Aquatic Habitat Assessment

1 ½ Mile Reach – GE-Pittsfield/Housatonic River Site, Pittsfield, MA

September 29, 2000

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1.0 Purpose

The purpose of this report is to document the existing aquatic habitat conditions and to clarify habitat restoration objectives (HROs) for the 1 ½ Mile Reach[1] of the Housatonic River, Pittsfield, Massachusetts. The 1 ½ Mile Reach is a portion of the overall GE-Pittsfield/Housatonic River Site and is defined as the section of the East Branch of the Housatonic River and its riverbanks from Lyman Street to the confluence of the West Branch of the Housatonic River. The 1 ½ Mile Reach excludes actual/potential and other non-riverbank portions of the floodplain properties adjacent to the Reach (United States of America et al. vs. General Electric Company, 1999).

A general description of the HROs for the 1 ½ Mile Reach were previously defined in an Engineering Evaluation/Cost Analysis (EE/CA) report prepared in February 2000 (R.F. Weston, 2000). HROs were developed to insure that the functions and values that the aquatic and riparian habitats provide are maintained and enhanced following the removal action, and that restoration is performed in accordance with the Consent Decree, as described below.

- Implement the Removal Action for the 1 ½ Mile Reach as approved by EPA;
- Perform the restoration, including the enhancement of the river sediment and bank habitat, to increase the diversity and productivity of the biological community reach;
- Restore the riverbank to provide overlying cover, to enhance the bank vegetation by establishing plantings using native species; and
- Minimize the potential for erosion of residual PCB-containing bank soils and river sediments that would result in recontamination of river sediments or transport of PCBs, and which could impair the river restoration by adversely impacting the ecological receptors.

Besides the general HROs, which cover both the aquatic and riparian zones, the EE/CA included a description of planting requirements and specifications to meet the riparian objectives. The riparian HROs and related planting specifications, which were well described and detailed, are not repeated in this report.

In July 2000, Woodlot Alternatives, Inc. (Woodlot), conducted an aquatic habitat assessment by collecting existing conditions data on physical habitat, water quality, and fish and benthic macroinvertebrate utilization to supplement the aquatic HROs with more site-specific information. The results of the 2000 assessment, along with input from the Natural Resource Trustees[2], were used to develop the supplemental aquatic habitat restoration objectives presented in this report.

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[1] Historically, the 1 ½ Mile Reach area has been referred to as the EE/CA reach.

[2] Trustees include the Commonwealth of Massachusetts (represented by the Massachusetts Executive Office of Environmental Affairs), the Department of the Interior (represented by the United States Fish and Wildlife Services), the United States Department of Commerce (represented by the National Oceanic and Atmospheric Administration), Massachusetts Department of Environmental Protection, United States Army Corps of Engineers, United States Environmental Protection Agency, and the State of Connecticut.

2.0 Aquatic Habitat Assessment

Aquatic habitat is composed of three primary components: physical, chemical, and biological characteristics. Physical characteristics include such features as pools and riffles, or channel dimensions. Chemical characteristics encompass a broad range of variables such as PCB sediment concentrations or water pH. Biological characteristics consist of measurable components of the ecological community (e.g., macroinvertebrate diversity) that describe the composition of flora and fauna species that inhabit the river.

For this assessment physical characteristics are measured in the field and summarized. Only the current water quality conditions are summarized since other chemical components (e.g., PCB levels) have been described elsewhere. The assessment also includes the characterization of the biological communities (i.e., fishes and benthic macroinvertebrates), which serves as a relative biological index since they integrate physical habitat and water quality conditions (e.g., riparian vegetation, water temperature). Both existing and new data have been integrated into this assessment.

All of the components described above are individual components of a larger picture – the aquatic ecosystem that is present at the site. For example, water velocity is a physical habitat characteristic that is critical in determining the distribution of organisms particularly macroinvertebrate species such as caddisflies. Caddisfly species utilize tiny nets that are constructed on stable substrates like large pieces of wood or in the interstices between rocks where the current carries sufficient organic detritus to support the organisms but does not flow at such high velocity that it destroys the nets (Cummins, 1974). Hence, characterizing habitat components and assessing habitat needs can be complex since altering habitat at both macro- and micro-habitat levels can create opportunities for some species while decreasing potential utilization for others.

All of the habitat components vary over both spatial and temporal scales. Some water quality parameters (e.g., water temperature) can change hourly depending on site conditions, whereas some physical components, such as a bedrock constrained pool, can be maintained within the same location over many years. Biological characteristics such as the number of fish species or the population dynamic of an individual species can vary daily, seasonally, and annually depending on age classes, life histories, morphology, feeding and migration patterns, food availability, competition, predation, and contaminant effects.

The interrelationship of the habitat components is also greatly influenced by high and low flow events that can affect some or all of these components by altering structure or water quality. Such events can create both short-term and long-term effects on the aquatic ecosystem. For example, during drought periods dissolved oxygen may be temporarily reduced or a large flood may permanently alter channel morphology by filling in a pool with fine sediments. The range and frequency of historical flow events have been previously described in the EE/CA document (R.F. Weston, 2000).

Of the three principal habitat components, physical habitat is the component that can be directly altered as a result of habitat reconstruction (e.g., changes in hiding cover types). Biological, water quality, and water quantity are, to some degree, independent variables (except for the removal of contaminated sediments which may directly affect biological characteristics such as reproductive health).

For example, water pH or the species composition of the fish community cannot be physically modified during the reconstruction of the riverbed. The reconstruction of the riverbed, however, may influence by design the likelihood of recolonization by certain species. Nonetheless, existing water quality and biological habitat conditions are discussed in this report because some parameters (e.g., water temperature) will ultimately affect species recolonization, utilization, diversity, and productivity once habitats have been reconstructed.

Besides providing details on current conditions to help meet restoration objectives, the aquatic habitat assessment also needs to describe baseline conditions that can be utilized to evaluate the restoration efforts during the long-term monitoring period. The aquatic habitat assessment is conducted during low flow periods since habitat characteristics can change with river flow levels. For example, pools can become "washed out" at high flows and subsequently influence the monitoring evaluation results. At low flow levels the assessment provides a unique morphological signature of the river's structure that can be re-measured during the monitoring period to assess riverbed restoration efforts.

3.0 Objectives

The primary objective for conducting the baseline aquatic habitat assessment is to define and quantify the existing aquatic habitat conditions within the 1 ½ Mile Reach. Once these conditions have been defined they can be used to:

- Refine and clarify the habitat restoration objectives that were initially defined in the EE/CA;
- Develop habitat reconstruction plans to insure habitat types are restored during site remediation; and
- Provide a basis for comparison between pre- and post-construction/restoration so that the habitat restoration objectives can be evaluated during the long-term monitoring period.

4.0 Study Area

The aquatic habitat survey was conducted on the East Branch of the Housatonic River in Pittsfield, Massachusetts from the Lyman Street Bridge to the confluence with the West Branch of the Housatonic River for a total length of approximately 1.4 miles. The segment has been further divided into three distinct reaches based on geomorphic conditions and the sequence of the proposed site remediation work (Figure 1). The approximate reach locations and their respective river lengths are defined as:

- **Reach 1:** Lyman Street Bridge to Elm Street Bridge (2100 feet)
- **Reach 2:** Elm Street Bridge to Dawes Avenue Bridge. (2200 feet)
- **Reach 3:** Dawes Avenue Bridge to confluence with West Branch of the Housatonic River (3100 feet)

5.0 Methods

5.1 Physical Characterization

Physical characterization is divided into seven general habitat attributes that are important in influencing the river's aquatic ecology (Kaufmann, 1993). These attributes are described below and include: channel dimensions, channel gradient, channel substrate size and type, habitat complexity and cover, riparian vegetation cover and structure, land-use alterations, and channel-riparian interactions. Each of these attributes were measured and assessed during habitat characterization. The field methodologies for each attribute are described below.

Assessment methodologies vary depending on the parameters measured, river size and length, time of year, and the cost and time constraints of the project but generally fall into either qualitative or quantitative methods. Qualitative methods can be conducted rapidly by interpreting field observations and then comparing these results to the "natural" expectation (i.e., conditions in a relatively undisturbed reach) or to a set of reference criteria (e.g., Rapid Bioassessment Protocols (Barbour *et al.*, 1999)) to rate the existing conditions as good, fair, or poor.

Quantitative methods collect habitat data at systematically spaced transects along the length of the river that ultimately can be used to represent average conditions for a particular reach. This type of approach is utilized for this assessment since more detailed measurements are needed for refining the restoration objectives. Additionally, portions of the 1 ½ Mile Reach have had significant land-use alterations (e.g., channelization) and a "natural" condition may be difficult to quantify.

The 1 ½ Mile Reach is comprised of various channel units such as pools or riffles, which are the building blocks for hydraulic and biological characterization. Within these channel units exist a variety of characteristics (e.g., substrate, woody debris) that support an array of functions and processes (e.g., spawning areas, velocity dissipation) that ultimately define the habitat complexity of these units.

To define these channel units in the field, a channel feature and dimension technique was utilized (Bain and Stevenson, 1999). This technique uses a set of channel shape and hydraulic measurements and is based on the concept that distinct channel units have characteristic gradient, water velocity, turbulence, substrate, and formative features (e.g., scour zone). Pools, for example, are units where water surface gradient is nearly flat, velocity is slow, water depth is relatively deep, and a hydraulic control is present (e.g., impoundment by boulders).

For the objectives of this report the channel unit classification system developed by Hawkins *et al.* (1993) is used for this assessment. Within the study area, there are three primary channel unit types: pools, riffles, and runs. In order to be classified as a channel unit, such in-stream features must be greater or equal to the wetted width of the channel (i.e., channel width at low flow). Pools had to also contain a well-defined hydraulic control feature. Units that satisfied these criteria were delineated as major channel units. Smaller features that still contributed habitat components (e.g., pools along the channel margin within a larger run) were classified as minor channel units.

Within randomly selected channel units, habitat characteristics (e.g., in-stream cover, velocity) were systematically measured along a tape-transect line placed perpendicular to river flow. Transects were spaced 200 to 300 feet apart, depending on the reach length, such that 10 transects were measured in each reach. The spacing was determined based on the resolution needed to characterize the habitat accurately for the study objectives and satisfy the time and cost constraints of the project. These transects are referenced according to nomenclature developed by R.F. Weston, Inc. (Weston), during soil characterization studies in 1999 (R.F. Weston, 2000). Soil transects begin at T064 in Reach 1 and end at T212 at the confluence of the East and West Branch in Reach 3, and are spaced 50 feet apart.

Additional habitat attributes, such as riparian canopy cover, were also measured to describe baseline conditions. All channel and habitat measurements followed established protocols and guidelines (Bain and Stevenson, 1999; Murphy and Willis, 1996). Some measurement techniques, however, were modified as necessary to fit site-specific conditions. For example, channel substrate was measured along the entire transect instead of only a specific distance (i.e., 25% of the channel width) since the substrate conditions were relatively homogeneous and the additional information gathered would improve overall accuracy.

Data collection began at the confluence of the West Branch of the Housatonic River (Reach 3) and progressed upstream to the Lyman Street Bridge (Reach 1). The channel and habitat characteristics measured at each transect are listed below. Their associated definitions and measurement methods are described in Appendix A.

- Channel width (wetted, bankfull)
- Channel depth (average, maximum, bankfull)
- Wetted perimeter
- Substrate
- Velocity (average)

- In-stream cover
- Canopy density
- Bank stability

Photographs were taken at the center of each transect (upstream, downstream, left bank, and right bank) to visually characterize the site. Selected transect photographs will be used over the monitoring period to reference restoration efforts.

As transect measurements progressed upstream, additional channel characteristics were measured and delineated on the previously developed river plan map (Woodlot Alternatives, 1999) to further characterize the aquatic habitat between transects. Characteristics that were previously mapped in 1998 were also updated as necessary (e.g., location of woody debris). Characteristics mapped include:

- Channel unit (location, size)
- Residual pool volumes
- Pool types (formation process and causal element)
- In-stream woody debris (location, size)
- Anthropogenic alterations (bank riprap, outfalls)

Channel units were delineated based on the shape, size, and geomorphic criteria listed earlier. Residual pools were also identified and measured (Appendix A). These are pools that would still retain water if the river flow were to approach zero (Lisle, 1991). Riffles and runs would "dry up" at such theoretical flows; hence, only pools are measured. They can be measured independent of flow in the field and represent a unique morphological signature that describes the riverbed topography. For each residual pool, depth, width, and length were measured and residual pool volumes estimated. Additionally, at each pool location, the formation type (e.g., lateral scour) and the feature type (e.g., boulder), according to Hawkins *et al.* (1993) classification system, were recorded.

Appendix A describes in more detail how residual pool volumes were estimated as well as the criteria employed to map in-stream woody debris. The field form utilized to collect channel and habitat characteristics is also included in this appendix.

5.2 Water Quality Characterization

The intent of this section is to document existing conditions related to four commonly observed water quality parameters: (1) temperature, (2) dissolved oxygen, (3) turbidity/suspended solids, and (4) pH. The primary methods for obtaining this information for this assessment were to utilize existing water quality databases and to directly evaluate these parameters within the 1 ½ Mile Reach during the summer months. Below are brief descriptions of each parameter and the methods used to define existing conditions.

Temperature

Water temperature is an important attribute of a river, affecting the survival, growth, reproduction, incubation, migration, and habitat use of fishes, as well as the availability of dissolved oxygen. River temperatures fluctuate daily and seasonally, and are affected by the exposure to direct sunlight, flow levels, groundwater input, air temperature, and human influences (e.g., industrial or municipal thermal pollution).

Critical life history variables for fish (and all aquatic organisms) are regulated by temperature (Hauer and Lamberti, 1996). Most freshwater fish can tolerate a relatively wide range of temperatures, although each species prefers a specific range within which growth, reproduction and survival are optimized. For example, some species, such as brook trout (*Salvelinus fontinalis*), exhibit a more rigid requirement in regard to upper and lower temperature thresholds, requiring a year-round supply of cold, oxygenated water for survival. Others, such as white sucker (*Catostomus commersoni*), are adaptable to a much wider range of temperatures.

Woodlot collected temperature measurements from July 1 to August 28, 2000, using Onset Tidbit® data loggers within each of the three reaches within the 1 ½ Mile Reach. Specific recording locations were at: Transect 74 (Reach 1, Lyman St. Bridge), Transect 110 (Reach 2, Elm St. Bridge), and Transect 202 (Reach 3, near Fred Garner Park). Besides baseline characterization of summer water temperatures, the locations were also chosen because they are at the beginning or end of a reach and would provide water temperature information that could be used during long-term monitoring (e.g., assess restoration efforts). Loggers were installed in channel units that had relatively swift, well-mixed waters such as riffles and runs. The data loggers were programmed to collect hourly temperature readings.

Weston collected water temperature data (along with other water quality information) at 17 sampling locations along the Housatonic River and its tributaries during monthly surface water samplings from August 1998 to October 1999 (R.F. Weston, 1999). Three of the sampling stations were located within the 1 ½ Mile Reach at the bridges on Pomeroy Avenue (station 08), Elm Street (station 09), and Lyman Street (station 10). The monthly measurements for each station were tabulated for the period of record.

Dissolved Oxygen (DO)

Dissolved oxygen (DO) is the concentration of oxygen dissolved in the water, where saturation is the maximum amount of oxygen that can theoretically be dissolved at a given altitude and water temperature. The solubility of oxygen generally increases as temperature decreases. DO concentrations are not uniform within or between stream reaches due to variations in depth, temperature, turbulence, microhabitats, algal growth, time of day, groundwater inputs, and organic pollution (municipal sewage and industrial waste). DO greatly affects all aquatic life, both plant and animal (Hauer and Lamberti, 1996). Reduced DO can have a significant adverse affect on fish swimming performance, migration, incubation, juvenile rearing, and growth (USEPA, 1986).

Dissolved oxygen data were obtained from Weston's monthly surface water sampling effort from August 1998 to October 1999 from the three locations previously described.

Turbidity/Suspended Sediment

Turbidity refers to the relative clarity of a water body, as well as the extent to which light penetration in the water column is reduced by the presence of suspended materials (i.e., clay, mud, organic matter, plankton). It is often measured in neophelometric turbidity units (NTU) or other standards (Armantrout, 1998). The higher the turbidity, the lower the clarity. High turbidity in a stream may be a short-lived phenomenon (e.g., flood), or it may be a more static condition that is a function of the particular stream and watershed (e.g., geology). Sources of inorganic and organic sediment in a stream include surface erosion within the watershed, riverbank and bed erosion, and various types of mass wasting processes (e.g., slumps, landslides). Highly turbid water with fine suspended and deposited sediment can affect fish by clogging or abrading their gills or reducing the survival of eggs laid in the bed substrate (Reiser and Wesche, 1977).

Turbidity data were obtained from Weston's monthly surface water sampling effort from August 1998 to October 1999 from the three locations previously described.

pH

pH is a measure of the acidity and alkalinity of water, expressed as the negative $\log_{10}$ of the hydrogen-ion concentration on a scale of 0 (highly acidic) to 14 (highly basic), with 7 being neutral. Excessive acidity or alkalinity, which can result from human pollution (e.g., mining) or natural causes (e.g., soils, rocks and plant communities), is potentially lethal to most fish species. Waters with pH values above 8.5 or below 5.0 support only a few tolerant fish species, whereas most freshwater fish are capable of living within the pH range of 5.0 to 8.5 (Moyle and Cech, 1982).

pH data were obtained from Weston's monthly surface water sampling effort from August 1998 to October 1999 from the three locations previously described.

Several other sources were also investigated for temperature, DO, turbidity, and pH data. No relevant data were available from these sources, which included the Massachusetts Department of Environmental Protection, the local USGS gauging station at Coltsville, MA (just upstream from Pittsfield), the USGS National Water Quality Assessment (NAWQA) Program regional office in Northborough, MA, and General Electric Corporation, Pittsfield, MA.

5.3 Biological Characterization

Biological communities reflect overall ecological integrity by integrating physical, chemical, and biological habitat conditions. Thus, the evaluation of these communities can be diagnostic indicators of river health. Two of these communities, fishes and benthic macroinvertebrates, have been characterized for this assessment. These two communities will also influence the potential habitat limitations for restoration planning.

Fish

In September and October of 1998, USFWS, USEPA, Weston, and Woodlot jointly collected fisheries data from locations upstream and downstream of the 1 ½ Mile Reach on the Housatonic River (R.F. Weston *et al.*, 1998). These data were obtained from electrofishing surveys using both backpack and boat-mounted gear. Representative sections of the river were fished for 0.5-hour periods to characterize the species richness and relative abundance. Chadwick and Associates, Inc. (Chadwick, 1994) also assessed fish populations using electrofishing surveys during 1992 and 1993 on the Housatonic River from Pittsfield, Massachusetts downstream to the Connecticut border.

Both studies were essentially qualitative in nature, and no information on biomass or other population parameters was collected. Numbers of each species captured were recorded. Although neither study conducted sampling within the 1 ½ Mile Reach, some of the data collected, particularly those sites on the Housatonic River within 3 to 5 miles of the 1 ½ Mile Reach, are applicable since these sites contain similar habitat conditions.

To characterize the fisheries, both studies were employed to estimate the relative abundance of fish species known to occur near the 1 ½ Mile Reach. Abundance was classified as: (1) Abundant (large numbers recorded); (2) Common (many recorded); or (3) Uncommon (present, but few recorded).

Available information on general habitat preferences, spawning habitat, and preferred temperature and pH ranges was gathered for each of the fish species. The main source for this information was FishBase99, a comprehensive web site containing a compilation of data from worldwide research (www.fishbase.org). Another source was a New Hampshire Fish and Game Department publication entitled *Freshwater Fishes of New Hampshire* (Scarola, 1973).

Benthic Macroinvertebrates

Benthic macroinvertebrates are groups of aquatic insects that live primarily along the bottoms of water bodies and can be seen without magnification. Orders within this group are diverse and include such insects as mayflies (Ephemeroptera), stoneflies (Plecoptera), and beetles (Coleoptera). These insects provide a variety of functions within the river system and are particularly important in processing and breaking down organic material and providing a primary food source for fish. General functional groups include collectors, predators, scrapers, and shredders.

Benthic macroinvertebrates are good indicators of localized conditions since many benthic macroinvertebrates have limited migration patterns or a sessile mode of life. Macroinvertebrate assemblages are made up of species that constitute a broad range of trophic levels and habitat tolerances, thus they provide indications of overall river ecosystem health. Characterizing these assemblages can also be used during long-term monitoring to assess restoration efforts.

Macroinvertebrate samples were collected from one representative riffle or run within each reach during low flow conditions to characterization the community. Sampling procedures followed established methods to assess single habitat types (Barbour *et al.*, 1999). Sample sites reflected, to the maximum extent possible, the associated average reach conditions based on substrate, riparian cover, and channel width, depth, and velocity.

At each representative reach site 12 samples were collected using a 9 by 18 inch rectangular dip net with a 500-micron net. The 12 sample locations for each transect were equally spaced (approximately 5 to 10 feet apart) and transversed the channel width in an upstream zigzag pattern. A one meter square grid was employed upstream of the net to define the sampling area at each sample location. The bed substrate was "kicked" for approximately two minutes during each sample collection. All samples were preserved in 1-liter plastic containers with 95% ethanol in the field, and then shipped to a laboratory for taxonomic identification.

At each of these transects, a 10 g sample was collected using the dip net to characterize the macroinvertebrate tissue PCB concentrations. The predominant taxa used for the PCB tissue analysis was determined in the field at each transect during the collection of the macroinvertebrate community characterization sample. Samples were placed in a precleaned 4-ounce glass jar with river water during collection and placed on wet ice for return to the laboratory.

In the laboratory, samples were drained, weighed, and preserved by freezing at approximately 0° F. Samples were then shipped frozen to the analytical laboratory for PCB tissue analyses (i.e., total, Aroclors, congeners, homologs).

6.0 Results

6.1 Physical Characterization

The aquatic habitat survey was conducted on July 24, 25, and 26, 2000, during typical low-flow conditions (34 to 38 cfs). This section summarizes the results derived from mapping the habitat features throughout the 1 ½ Mile Reach (e.g., channel unit types, woody debris) and from measuring habitat characteristics collected at specific transects for each of the three reaches.

Appendix B illustrates the type, size and location of channel unit, woody debris, large boulders, in-stream bar deposits, and miscellaneous channel features (e.g., bank armor) on a series of river plan maps. Habitat characteristics such as velocity, cover, or substrate that were measured at each transect are tabulated in Appendix C. Statistics were calculated for each of the various characteristics for each reach and are described below.

Besides average and range statistics, standard deviation is also described because it represents a variability component that may provide an index of the degree of habitat complexity. Often, higher variability for specific habitat characteristics is due to a wider range of habitats, each of which is used by aquatic organisms. Therefore, increased habitat often means there is a more diverse biological community.

For example, greater variability in channel depth may indicate that a wider range of velocities occur, compared to a reach where channel depth is homogenous. The wider ranges of velocity may provide increases in available habitat and subsequently in species utilization. The degree of utilization, however, depends on the interaction of other habitat components (e.g., substrate type, water quality), the specific species present, and their associated life histories.

Individual habitat characteristics are assessed separately below to locate specific characteristics to maintain, or to highlight features that could be enhanced during restoration activities.

Channel Units

Channel units are relatively homogenous areas of the river that differ in depth, gradient, velocity, substrate, and channel morphology from adjoining areas, which create different habitat types. Pools, riffles, and runs are the three channel unit types relevant to this study. These features provide a variety of habitat conditions for different aquatic organisms.

For example, pools typically have slower velocities and deeper water depths and can provide both rearing and hiding cover for various fish species (e.g., northern pike (*Esox lucius)*, largemouth bass (*Micropterus salmoides),* common carp (*Cyprinus carpio*)). While riffles and runs provide relatively faster moving water for different fish species (e.g., longnose dace (*Rhinichthys cataractae*)), and depending on the substrate type can also provide downstream food sources such as macroinvertebrates. Channel units also influence hydraulic features of a river such as energy dissipation in pools and subsequent erosion reduction downstream.

Figure 2 shows the relative abundance of channel units (based on the length) for each of the three reaches. Reach 1 has the lowest number of total channel units (5) while Reach 2 has the greatest (17). Reach 2 also has the greatest number of both pools and riffles (6 and 8, respectively) while Reach 3 has the greatest number of runs (5). Diversity of channel unit types is lacking in Reach 1.

Reach 1 has the least number of pools, however, this reach conversely has the highest relative percentage of pools (70%). This is a result of one relatively large pool that extends approximately 830 feet upstream of the Elm Street Bridge. This pool is a result of the low reach gradient (<0.1%) and the bedrock outcrop directly beneath the bridge that causes water to impound upstream.

In Reach 2, both average gradient (0.5%) and bed substrate size (cobble) have increased as a result of the underlying bedrock in this reach. These changes help develop the well-defined pool and riffle patterns: approximately 50% riffles and 30% pools. The general effects of bedrock are reduced in Reach 3; the gradient and substrate size decreases, which ultimately affects the channel unit types (i.e., riffles reduce and runs increase).

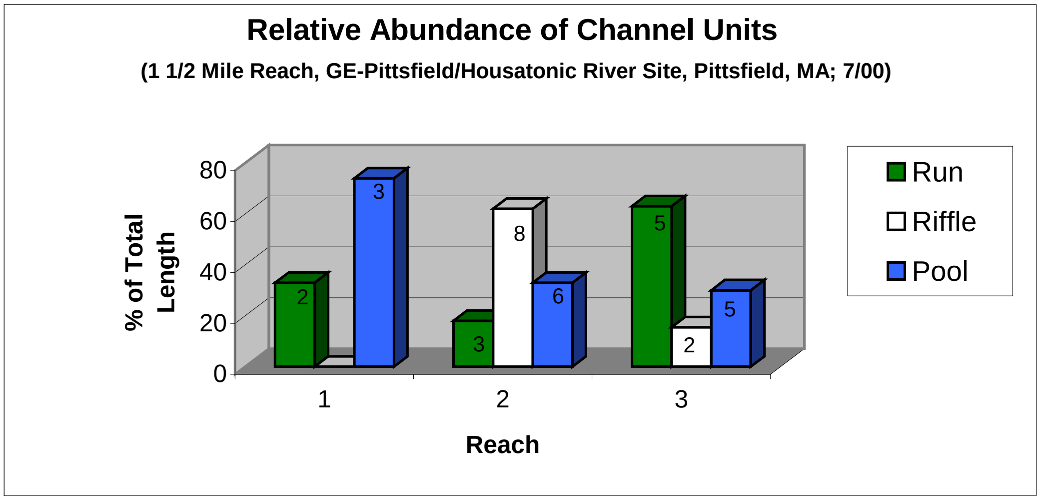

Figure 2. Relative abundance of channel units for Reach 1, 2, and 3 (numbers inside the bars represent the quantity of specific units).

Besides the relative abundance of channel units, residual pool volume is a unique riverbed signature that integrates the riverbed topography by measuring pool depth, width, and length (Appendix D). Residual pool volume calculates the volume of water that would be retained in the riverbed if the flow approached zero (Lisle, 1991). Theoretically, as flow approaches zero, riffles and runs would "dry up," and only pools would still hold water. Hence, only pools are measured. Residual pool volume measurements are independent of flow and thus can be assessed at any river flow level. Specific residual pool volume measurements are described more fully in Appendix A.

Figure 3 illustrates the residual pool volumes for each reach. Reach 1, with three pools, has 4 to 6 times the residual volume of Reaches 2 or 3 that have approximately twice the number of pools. This is due, as mentioned above, to the large pool located upstream of the Elm Street Bridge. This pool makes up approximately 85% of the total residual pool volume in Reach 1.

Typically for rivers the size of the Housatonic River, pools are rhythmically spaced 5 to 7 channel widths apart where the channel width is equal to the average bankfull width (Keller and Melhorn, 1978). Reach 1, 2, and 3 had average pool-to-pool spacing of 13, 7, and 14 channel widths respectively. This indicates that the percentage of pools in Reach 2 approaches an acceptable range whereas Reaches 1 and 3 have too few pools that are spaced too far apart. The pool-to-pool spacing in Reach 1, however, is skewed due to the relatively long pool that exists near the Elm Street Bridge.

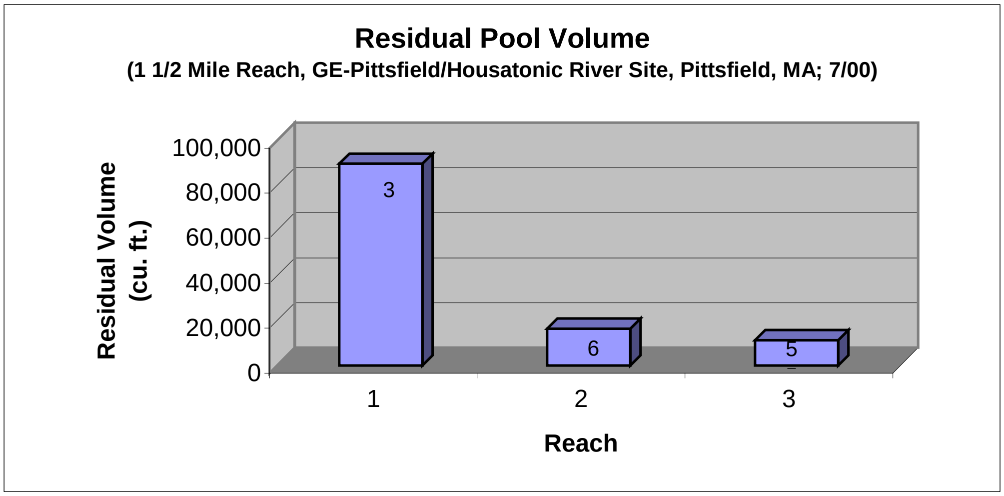

Figure 3. Residual pool volume for Reach 1, 2, and 3 (numbers inside the bars represent the quantity of pools in each reach).

Primary pool forming processes define the pattern water flows to create a pool. These include such processes as plunge, lateral scour, or impoundment. Pool forming elements help the pool forming process develop (e.g., water plunging over woody debris). Examples of pool forming elements include boulders, woody debris, or channel bends. Both the primary pool forming process and element are summarized in Appendix D for each reach.

For Reach 1, the primary pool forming processes were impoundment (bedrock ledge) and lateral scour. The lateral scour pools were located on the outside of river bends. As the gradient and substrate size increased in Reach 2 pools formed by plunging water increased. This reach consisted of approximately 50% plunge, 30% lateral scour, and 20% impoundment. Plunge and impoundment pools were associated with bedrock or boulders.

In Reach 3, where river gradient and substrate size decreased, all of the pools were formed by lateral scour. Pools in this reach were located on the outside edge of river bends and along the channel margin where woody debris had accumulated.

Within all three reaches lateral scour pools typically had a narrow scour zone (25 to 50% of the channel width), were generally located along the outside portion of river bends with a deposition area on the inside (e.g., point bar), and were relatively long (200 to 400 feet) with average water depths of 2 to 4 feet. Plunge and impoundment pools were generally shorter in length, spanned the entire width of the channel, and had well-defined scour or impoundment zones.

Woody Debris

Woody debris includes trees, large limbs, boles, and root wads that meet the size criteria (i.e., >6 inch diameter and >25 feet in length). Woody debris enters the river system by bank erosion, blowdown, beaver activity, or collapse of trees due to ice loading. Depending on the size of woody debris and flow levels, it may remain in place or break into smaller pieces and be transported downstream to form debris jams. Woody debris may greatly effect channel form and process by: increasing or decreasing the stability of banks; influencing sediment transport (e.g., trapping gravel, bar formation); creating fish habitat (e.g., pools, cover), and providing substrate for macroinvertebrates. Appendix D summarizes the number of pieces and size classes of woody debris within each reach.

Reach 3 had pools that had formed as a result of lateral scour caused primarily by woody debris. These pools, generally, had smaller residual pool volumes than those associated with channel bends. Woody debris, however, was a very common secondary pool-forming element in all three reaches. For example, a pool in Reach 1 (P2) was primarily formed by lateral scour due to a channel bend but a logjam within it altered its overall bed morphology and enhanced habitat functions. These functions include providing in-river food sources, hiding cover, and diversity in velocity patterns.

Woody debris pieces were highest in Reach 1 and 3, with 39 and 46 pieces, respectively. Reach 2 had the lowest (13 pieces), which correlates with the higher shear stresses in this area (steeper river gradient) where woody debris would have a higher tendency to be transported downstream. In all three reaches approximately 90% of the woody debris consisted of small to medium size classes (6 to 24 inch diameter).

Compared to the 1998 river characterization (Woodlot Alternatives, 1999), about 50 to 75% of the woody debris **locations** have changed. New pieces were identified and previously mapped pieces were no longer present. Primarily the small to medium size classes have shifted. Overall the **net** change for all three reaches, however, was only an increase of 10%. Thus, pieces of woody debris shifted around but the number of pieces stayed approximately the same.

Individual pieces of the large size class and logjams have appeared to remain stable. These pieces or complexes were generally either primary or secondary formation features for pools within the reaches (e.g., P2, P9, and P14).

Channel Width, Depth, and Velocity

Additional important morphological parameters of physical habitat are channel width and depth, and the velocity within the habitat. These parameters are interrelated and influence each other. For example, a wide and deep channel will typically have lower velocities than a narrow and shallow channel, which would have relatively higher velocities for a given discharge. This interdependence influences the hydraulic variables of the channel such as shear stress, which also affects, to a limited extent, the aquatic species utilization (e.g., long nose dace prefers swift moving water while species like common carp or largemouth bass require deeper, slow moving water).

Figure 4 shows the range, average, and standard deviation of low-flow channel width for all three reaches[3]. Average channel width was highest in Reach 1 (55 feet) and lowest in Reach 2 (39 feet). Generally, channel width is inversely proportional to channel gradient and Figure 4 reflects this relationship (i.e., Reach 2 has the higher gradient and also has the smallest average channel width). Standard deviation of channel width was approximately the same for all three reaches: 6 to 7 feet, about 15% variability.

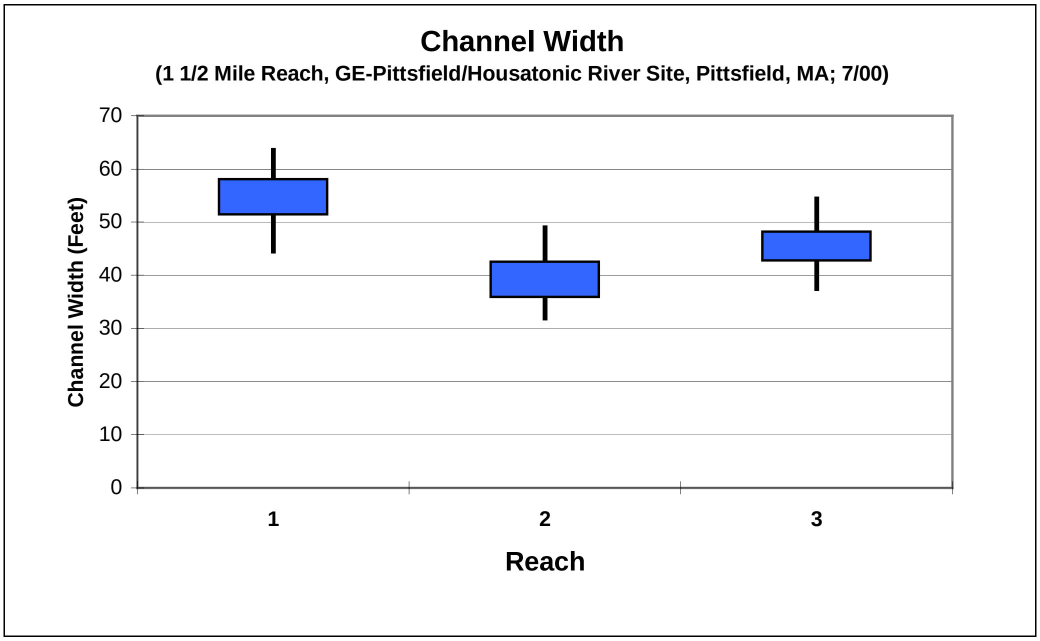

Figure 4. Range, average, and standard deviation for average low-flow channel width for each reach.

Figure 5 shows the range, average, and standard deviation of low-flow channel depths for all three reaches. The higher channel depth values in Reach 1 reflect the effects of the large bedrock-formed impoundment pool (P3). This reach had the highest range, average, and standard deviation (3.8, 2.6, and 0.9 feet, respectively) while Reach 3 had the lowest (2.1, 1.3, and 0.4 feet, respectively). When compared to the average, the standard deviation for Reach 2 corresponds to approximately 35% variability in channel depth.

Channel depth statistics appear to be dependent on the residual pool volumes in the reach (see Figure 3). Where residual pool volumes are high average channel depths are also high. Channel depth also influences other habitat conditions such as velocity, which then affects species utilization.

[3] This figure is a box and whisker plot. The box represents one standard deviation and the whisker shows the range. The average is located in the center of the box.

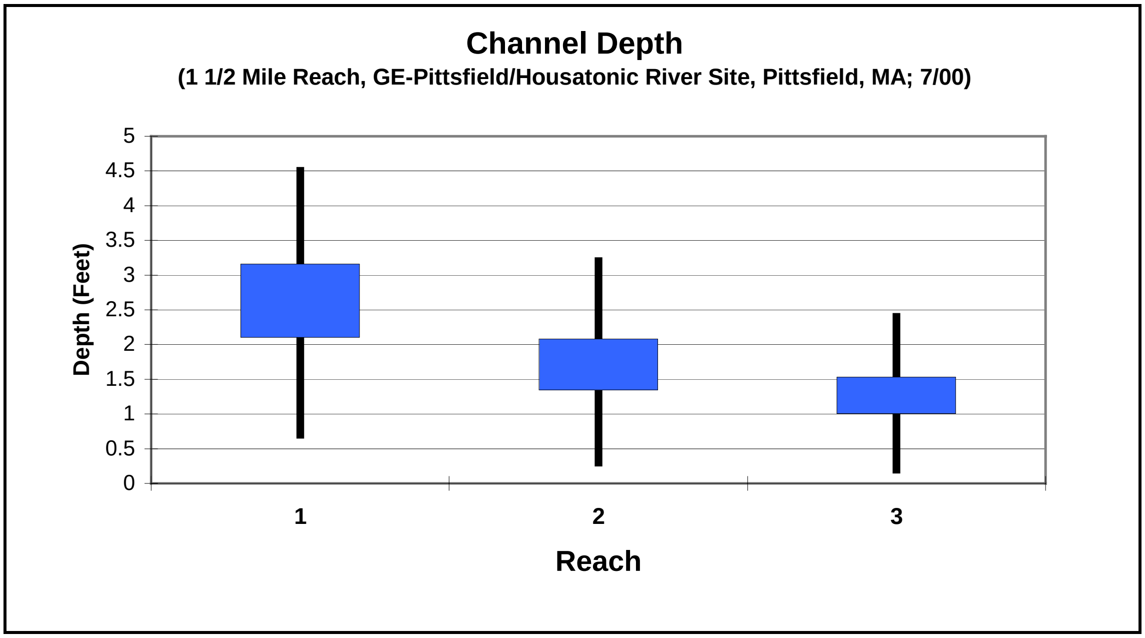

Figure 5. Range, average, and standard deviation for average low-flow channel depth for each reach.

Figure 6 illustrates the range, average, and standard deviation for low-flow velocity within each reach. Reach 1 has the smallest range of velocities for the three reaches, generally between 0.1 to 1.0 ft/s with an average of 0.4 ft/s. Reach 1 contains a relatively large impoundment pool with its associated slower velocities and has the lowest river gradient of the three reaches. Reach 2 and 3 show a much wider range of velocities, approximately 0 to 3.0 ft/s with averages approximately 3 times greater than Reach 1 (i.e., between 1.1 to 1.2 ft/s). This correlates with both the relative abundance of channel unit types (i.e., more riffles) and the overall steeper river gradient in these reaches.

The standard deviation also shows the same pattern: Reach 1 is approximately 0.2 ft/s while Reach 2 and 3, have 2 to 3 times the variability. The homogenous range of low-flow velocities in Reach 1 indicates that this area has a narrow range of fisheries utilization (e.g., primarily habitat for such species as rock bass (*Ambloplites rupestris*) black crappie (*Pomoxis nigromaculatus*), yellow perch (*Perca flavescens*), and sunfish (*Lepomis sp.*)).

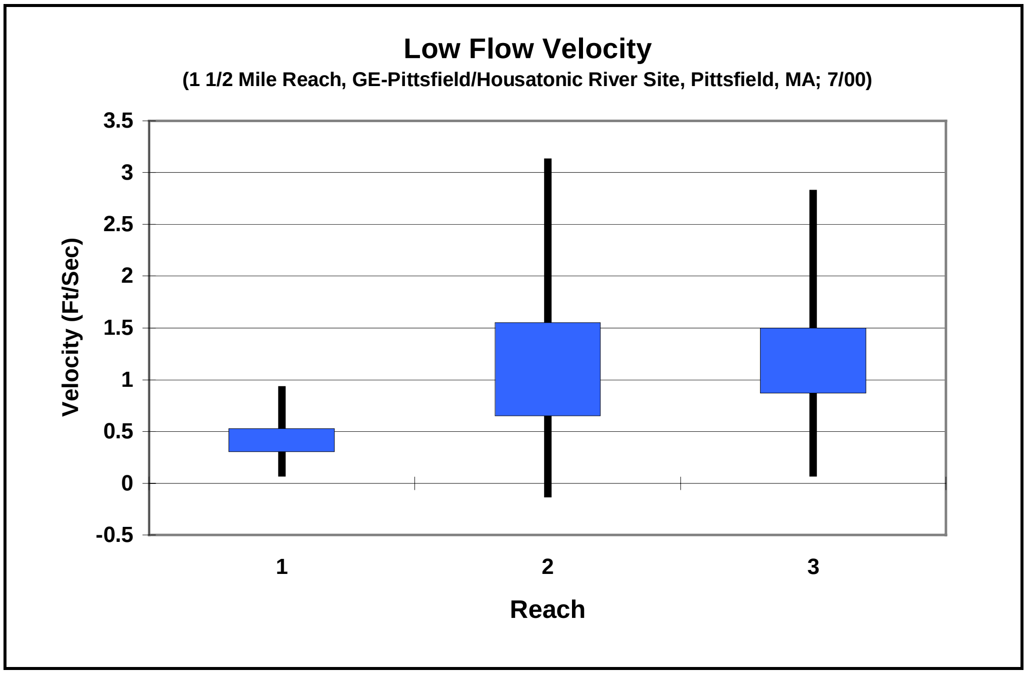

Figure 6. Range, average, and standard deviation for average low-flow velocity for each reach.

Bed Substrate

Substrate size is a function of water velocity, with larger materials associated with fast currents (e.g., boulder/cobble) and smaller materials (e.g., silt/sand) with slow-moving water. The dominant bed substrate indicates the relative potential amount of spawning habitat and hiding cover. The production of food sources such as macroinvertebrates are also dependent on substrate composition, which influences fish populations. The area of a cobble riffle, for example, is proportional to the number of fish in the downstream pool (Waters, 1969).

Figure 7 summarizes the average dominant substrate for each of the three reaches. Reach 1 is predominantly sand and silt/clay (70%) with small percentages of gravel and cobble. While Reach 2 (the "cobble" reach) is primarily cobble and gravel (75%) with smaller portions of sand, boulders, and bedrock. The majority of bed substrate in Reach 3 consists of sand and gravel (70%) with minor portions of silt/clay and cobble.

Bed substrate can be affected by upstream watershed management (i.e., urbanization, channelization), climatic patterns, and geology. Geology establishes the foundation for the river to carve through, which then influences channel dimensions, gradients, and substrate types. For example, Reach 2 is closely underlain with bedrock which affects the gradient of this reach as well as the local substrate ranges. All three reaches have been and are affected by broad-scale watershed management practices (e.g., urbanization) and local activities that change local river velocities and shear stresses, and ultimately influence the sediment transport rates (e.g., riprap along riverbanks protect from bank erosion but cause adjacent bed scour).

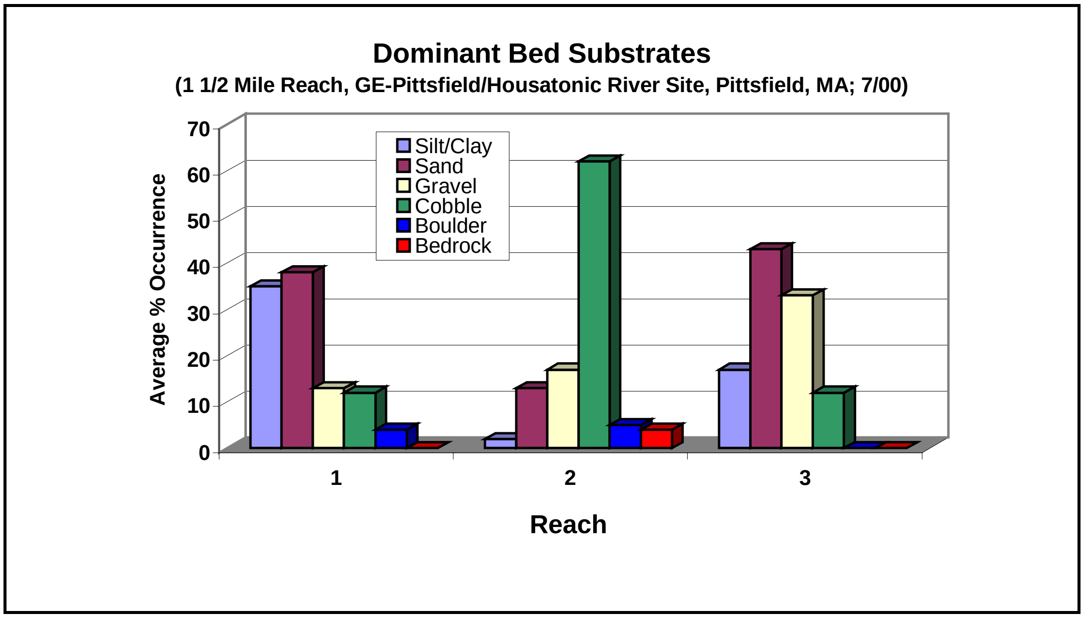

Figure 7. The average dominant bed substrates for each reach.

<u>In-Stream Cover</u>

Cover for fish can be provided by overhanging vegetation, undercut banks, large substrate (e.g., boulders), woody debris, aquatic vegetation, water depth, or turbulence (see Appendix A for definitions). Another cover type, trash (e.g., bicycles, shopping carts, cars), was added for the 1 ½ Mile Reach, because it provides cover as well. Cover can protect fish from predation and can provide shade and refuge from disturbance such as floods. During spawning and redd construction fish are vulnerable to predation and some species may select spawning sites based on the nearness to cover. For example, many spawning brown trout (*Salmo trutta)*, selected areas adjacent to undercut banks and overhanging vegetation (Reiser and Wesche, 1977).

Cover types are affected by the size of rivers. As river size increases, there is more energy to transport material such as woody debris downstream, compared to smaller rivers or streams that don't have the flow levels to transport woody debris. Thus, these rivers will have higher cover percentages in woody debris. Cover types are also influenced by the type of land-use activities along the river (e.g., navigation, riparian management, flood control).

Figure 8 shows the average percentage of each cover type for each reach. Cover types were measured along the transect and then changed to percent based on the width of the channel. Total cover is also described below and it represents the sum of individual cover types for each reach. This total can exceed 100% since some cover types may overlay each other (e.g., substrate and woody debris).

The total cover for Reach 1 was 60%. Water depth (30%) and substrate (15%) were the dominant cover types with the remaining 15% represented in bank vegetation, trash, and woody debris cover types. The cover associated with water depth was a result of the pools in this reach.

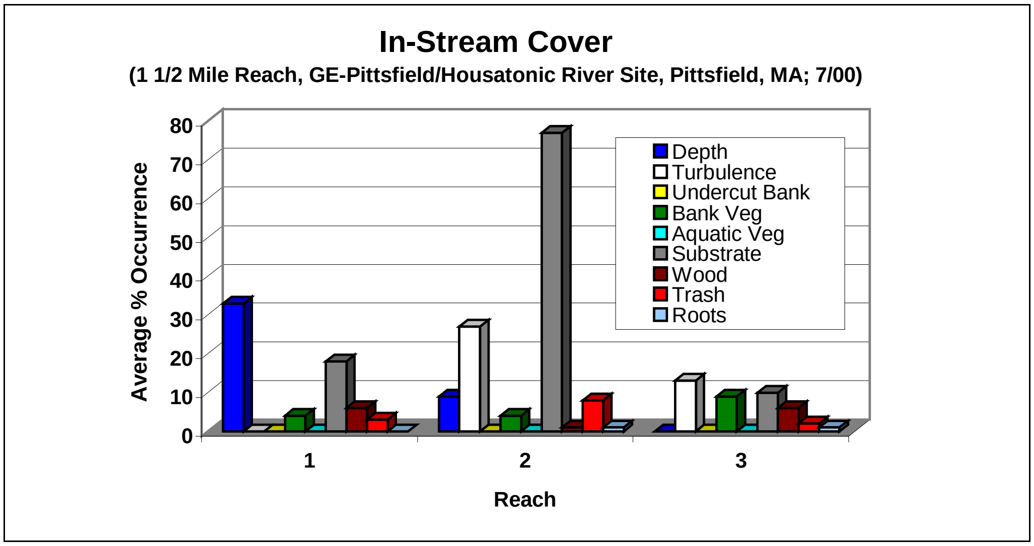

Figure 8. Average in-stream cover for each reach.

As the gradient increased in Reach 2 there are corresponding changes in substrate and the relative abundance of channel units. Substrate size increased to predominantly cobble with an associated increase in the percentage of riffles. These influence the dominant cover types in this reach. As Figure 8 illustrates, the dominant cover types were substrate (75%) and turbulence (25%) with additional minor contributions from water depth, bank vegetation, and trash. This reach had the highest total cover for the three reaches (120%).

Again, as the gradient changed in Reach 3 there were similar changes in substrate and channel unit types (i.e., finer substrate size and more runs, respectively). This reach had the lowest total cover, approximately 37%. Cover types consisted of equal portions of turbulence, bank vegetation, substrate, and woody debris (about 8% from each).

Bank Stability

Banks for all three reaches were very stable. Reaches 1, 2, and 3 were 94%, 98%, and 91% stable, respectively. This is primarily a result of the cohesive soil types and extent of riparian vegetation as well as the localized bank erosion control measures installed (e.g., rip-rap, gabions).

Riparian Vegetation Cover

The following section quantifies the amount of riparian vegetation that occurs over the river. A previous report (Woodlot Alternatives, 1999) provided detailed descriptions of the species composition, basal areas, vertical structure, and age classes of the riparian vegetation within the 1 ½ Mile Reach.

Riparian areas, or the area adjacent the river, are transititional areas between the aquatic and the terrestrial zones. They provide a variety of functions and processes such as reducing floodwater velocities, stabilizing riverbanks with vegetation, or providing travel corridors or cover for wildlife. For the context of this assessment, riparian vegetation was measured to determine the amount of cover it provides over the river. This cover then gives an indication of the extent of shading the riparian area provides that can affect water quality parameters (e.g., water temperature). Riparian cover may also be used to assess woody debris loads or in-stream cover differences between the different reaches. Lastly, existing riparian cover will provide a baseline that can be used during long-term monitoring to assess riverbank restoration objectives.

Figure 9 shows the range, average, and standard deviation of the percent of riparian cover for each reach. The average percent cover ranges from 50% for Reach 2 to 63% for Reach 3. Individual transect measurements ranged from approximately 30 to 90% with a slightly narrower band for Reach 2 (i.e., 30 to 75%). Reach 2 may have slightly lower ranges and average cover values due to the extent of urbanization along its banks.

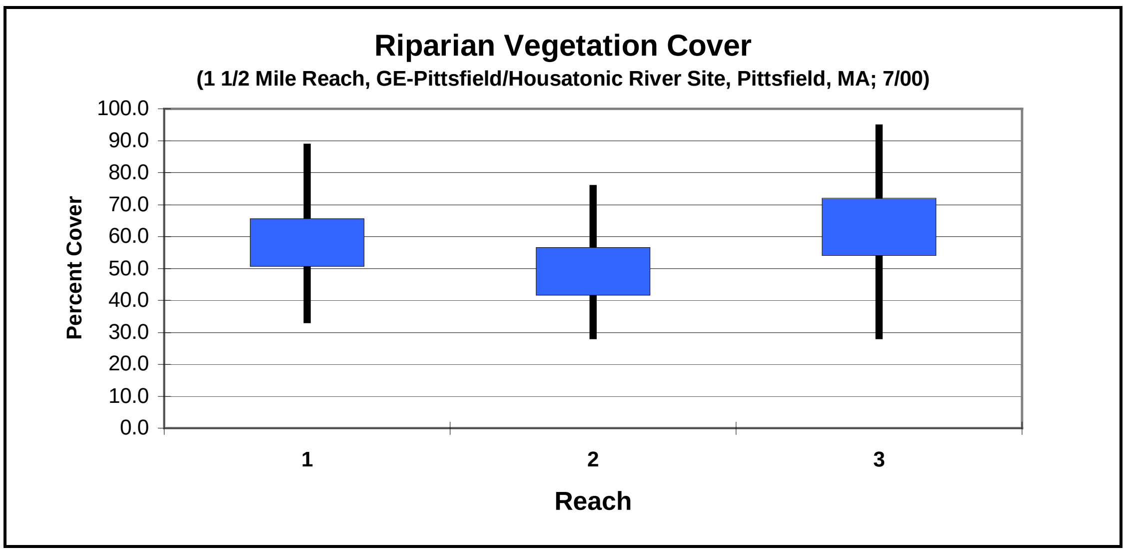

Figure 9. Range, average, and standard deviation for the riparian vegetation cover for each reach.

As described in Appendix A, riparian vegetation cover is measured in the center of the stream and near each bank. The average riparian cover ranges from 50 to 60%. Yet, in-stream cover for overhanging vegetation averages 6% for all three reaches. This is a result of the riparian vegetation not meeting the overhanging vegetation cover criteria (i.e., within the five foot or less of the water surface). Also, since the river widths are typically 50 to 60 feet wide, riparian vegetation does not extent over the entire river. For example, individual measurements near the channel margins have average riparian cover ranges from 70 to 95% but in the center of the river they are approximately 25% (Appendix C).

6.2 Water Quality Characterization

Weston (R.F. Weston, 1999) measured surface water quality conditions monthly from 17 sampling locations along the Housatonic River and its tributaries from August 1998 to October 1999. Three of the sampling stations were located within the 1 ½ Mile Reach at the bridges on Pomeroy Avenue (station 08- Reach 3), Elm Street (station 09 – Reach 2), and Lyman Street (station 10- Reach 1). The average values from these three stations for temperature, specific conductivity, dissolved oxygen, pH, and turbidity are summarized in Table 1.

Flow levels were not recorded during the surface water sampling effort. Flow values in Table 1 represent average daily discharge and were obtained from the upstream USGS station at Coltsville, Ma. (Socolow, 2000). During water quality sampling summer low-flow levels ranged from 14 to 26 cfs.

Table 1. Summary of R.F. Weston's surface water sampling results on the East Branch of the Housatonic River within the 1 ½ Mile Reach from August 1998 to October 1999.

Sample Date	Turbidity (NTU)	Temperature (^oF)	DO (mg/l)	pH	Flow (cfs)	Conductivity (μΩ/cm)
8/3/98	-	68.0	5.0	7.5	20	800
9/25/98	-	56.1	12.5	7.0	26	400
10/27/98	-	51.4	10.0	7.5	30	425
11/24/98	-	43.7	12.5	7.2	26	450
12/18/98	-	40.1	12.5	7.3	26	450
1/19/99	-	33.3	14.9	7.0	188	-
2/23/99	-	32.5	13.5	7.1	43	370
3/23/99	-	33.6	13.0	7.8	718	430
4/20/99	-	48.7	9.8	7.7	56	326
5/26/99	-	55.0	10.4	7.6	185	175
6/24/99	2.7	70.3	9.7	7.7	16	530
7/27/99	8.0	71.6	7.0	7.7	14	605
8/31/99	25.0	62.6	8.0	7.5	14	550
9/29/99	2.5	62.6	9.0	7.4	23	400

Notes: (1) "-" implies data not available.
(2) Flow measurements from USGS station on East Branch of the Housatonic River at Coltsville, Ma (station 01197000)

During the 1998 and 1999 summer low flow periods dissolved oxygen ranged from 5.0 to 9.7 mg/l, pH ranged from 7.0 to 7.7, specific conductivity ranged from 400 to 800 micro ohms/cm, and turbidity ranged from approximately 3 to 25 NTUs (1999 only).
Data loggers (i.e.,Tidbit®) were used to measure water temperatures every hour during low flow periods in July and August 2000 in Reaches 1, 2, and 3. Temperature data within Reach 1 from July and August of 2000, are illustrated Figure 10. The graphs for

Reaches 2 and 3 are not shown because the recorded temperatures were essentially identical for all three reaches.

The average water temperature for each reach for the 2-month period was approximately 66° F, while the maximum and minimum recorded temperatures were 74° F (on 8/9/00) and 57° F (on 8/21/00), respectively. Diurnal fluctuations varied from 2° F to 8° F, and again were essentially the same in each of the three reaches.

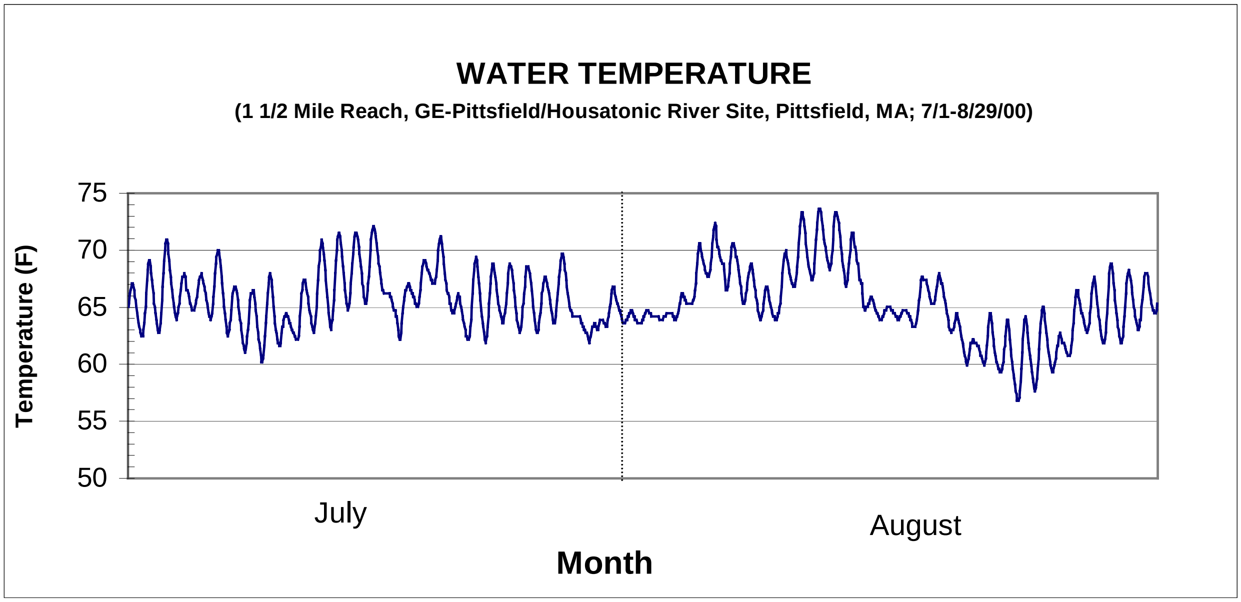

Figure 10. Water temperatures in the Reach 1 from July 1 to August 28, 2000.

6.3 Biological Characterization

Fish

Fisheries data from electrofishing surveys and literature searches are presented in the table contained in Appendix E. In summary, a total of 21 species were documented in the Housatonic within and near the 1 ½ Mile Reach. The most abundant species was yellow perch (*Perca flavescens*). Other common species include white sucker, largemouth bass, rock bass (*Ambloplitse rupestris*), bluegill sunfish, longnose dace, fallfish (*Semotilus corporalis*), as well as common shiners (*Luxilus cornutus*), spottail shiners (*Notropis hudsonius*), and golden shiners (*Notemigonus crysoleucas*). Some of the more important game fish documented downstream, but that were uncommon, include rainbow trout, brown trout, chain pickerel, northern pike, and smallmouth bass. Some of these uncommon species may in fact be transients, using the 1 ½ Mile Reach only to travel from upstream areas (where stocking occurs) to downstream areas.

In general, the species most commonly observed using the 1 ½ Mile Reach prefer habitats that contain aquatic vegetation and/or submerged woody debris, with sand, gravel, or rubble substrates and a mixture of riffles, runs, and pools. Most of the common species prefer relatively clear water, with tolerated temperature ranges from about 40^{o} F to the mid-to high 80s^{o} F. For those species where data was available, the pH preferences were all within the 7 to 7.5 range.

Benthic Macroinvertebrates

On August 17 and 18, 2000, Woodlot collected 12 macroinvertebrate samples from a representative riffle or run within each reach. The sampling stations were located at Transect 74 (Reach 1), Transect 136 (Reach 2), and Transect 170 (Reach 3). Discharge during sampling ranged from 150 to 200 cfs.

Preliminary results indicate a diverse population of macroinvertebrates at Transect 136 in Reach 2. Orders included beetles (Coleoptera), stonefly nymphs (Plecoptera), mayfly nymphs (Ephemeroptera), caddisflies (Trichoptera), flies (Diptera), and hellgrammites (Megaloptera). Reach 1 and 3, however, had relatively low populations. Segmented worms (Oligochaeta) were the only macroinvertebrates observed during collection.

These results appear to be primarily related to the substrate size and gradients within each reach. The transect in Reach 2 was comprised predominantly of cobble and a river gradient greater than 0.5%, which results in relatively fast flowing water (i.e., 1.5 to 2.0 ft/s). The other reach sampling transects consisted of largely silt and sand with minor portions of gravel, and had relatively flat river gradients and slower velocities (i.e., < 1.0 ft/s).

Macroinvertebrate samples were shipped to Lotic, Inc. (Unity, ME) for more rigorous taxonomic identification and community characterization on August 29, 2000. Results are expected in April 2001 and will be summarized in Appendix F.

Because Reach 1 and 3 had low relative populations of macroinvertebrates, the needed 10 g of sample could not be collected. Thus, only in Reach 2 where populations were higher, was a sample collected for PCB tissue concentration analyses. The dominant taxa collected for these analyses were of the Trichoptera Order (caddisflies). This sample was shipped in ice to Geochemical and Environmental Research Group (College Station, TX) for analyses on September 21, 2000. Results are expected in November 2000 and will be presented in Appendix G.

7.0 Discussion

Although there is a qualitative understanding of what makes "good" aquatic habitat (e.g., high percentage of hiding cover) based on field experience or the utilization of relative rating scales, the actual desired level may be quite variable amongst aquatic resource professionals. Also, reproducing the identical habitat may be difficult to attain during the reconstruction process since habitat characteristics influence each other and jointly comprise the "habitat" (e.g., reproducing bed scour from woody debris or hiding cover as a result of specific boulder combinations). This complexity increases further when biological and water quality characteristics are additionally considered.

For this physical habitat assessment, key habitat attributes were quantified. These attribute values were based on data collected along the entire river length within the study area and at specific measured transects during the low flow period. The results indicate there are distinct physical habitat differences between the three reaches. For example, Reach 1, 2, and 3 each contain a different dominant channel unit type: pools, riffles, and runs, respectively.

These baseline conditions can be used to add more site-specific details to the aquatic HROs; to assist in restoring habitat functions and processes during reconstruction activities; and to help develop long-term restoration monitoring plans so that HROs can be accurately assessed.

The results of this assessment can be used to implement the HROs by locating specific habitat characteristics that can be enhanced in each reach during reconstruction. Such enhancements would also increase the diversity and productivity of the biological community. Listed below are the habitat characteristics that could be enhanced within each reach. Appendix H describes in more detail this enhancement by developing a supplement for the HROs.

*Reach 1***:** Increase the variability in low-flow channel width and velocity, and increase the percentage of substrate and water turbulence in-stream cover types.

Reach 2: Increase the variability in low-flow channel width.

Reach 3: Increase the variability in low-flow channel width, and increase the percentage of substrate in-stream cover.

The habitat characteristics that could be enhanced were optimized to the maximum extent possible given the limitations of the remediation project. These limitations include other site remediation objectives and geomorphic constraints described below.

Other remediation objectives include protecting the bed and bank from erosion, maintaining or increasing the flood storage potential, and minimizing excavation and disposal costs (i.e., re-installing the same riverbed topography). These objectives affect habitat characteristics that can be enhanced, such as using woody debris as a cover component or creating deeper pool habitats. Conversely, some of these objectives may work constructively to enhance habitat, such as the installation of an armor layer. For example, the increase in substrate size may help increase the diversity of macroinvertebrates in Reach 1, if local areas can be scoured out seasonally (e.g., boulder placement).

Geomorphic limitations include river gradient, geology and associated substrate types, and the systematic spacing of pools and riffles (e.g., 5-7 channel widths). Additional indirect affects on restoration include the existing upstream watershed management (i.e., sediment loads), and the previous land-use history such as localized channelization, which limits the extent of restoration on river meander patterns or sinuosity.

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Appendix A

Aquatic Habitat Definitions, Methods, and Field Form

APPENDIX A

Aquatic Habitat Definitions, Methods, and Field Form

The terminology and methodology used to conduct the aquatic habitat survey are listed below. Generally, these terms and methods follow recommended protocols. More detailed discussion can be found in the references listed at end of this section. Some habitat characteristics, however, were modified to fit the site-specific conditions and objectives of the study. These included woody debris size classes, bank stability, and in-stream cover types (i.e., trash, water depth, overhanging vegetation).

Bank Stability: Pertains to the resistance of a river bank to erosion. For this study, bank stability was visually estimated by observing four quadrants at each transect. There were two quadrants on each bank, comprising 25 feet of bank directly upstream and 25 feet downstream of the transect. Data were recorded as the actual number of feet of stable bank for each quadrant, then expressed as the as a percent of the total observed bank (i.e., 25'x 4 = 100') that was stable. Bank sections were considered stable if there were no visible signs of ongoing erosion as evidenced by exposed or unstabilized soil within the 5-year flood stage level (approximately 5 feet above the low flow stage) (Barbour *et al.*, 1999).

Canopy Cover: The density of the trees and shrubs overhanging the river. Measurements were taken using a concave spherical densiometer to determine the extent of riparian cover over the river. Four measurements were taken at each transect (midstream- upstream and downstream, and along the banks- left and right) and then totaled. Data were expressed as the number of "hits" or intercepts by tree or shrub vegetation. Percent cover was then calculated by dividing the total number of hits for the transect by the total number of possible intercepting points on the densiometer (i.e., 68 for the particular instrument used in this study) (Bain and Stevenson, 1999).

Channel Unit: Relatively homogeneous areas of the river that differ in depth, gradient, velocity, substrate, and channel morphology from adjoining areas which create different habitat types. Channel units provide different habitat values to different fish and invertebrate species. Riffle, run, and pool are the three habitat types relevant to this study (Armantrout, 1998).

In order to be classified as a channel unit such in-stream features needed to be greater or equal to the wetted width of the channel. Units that satisfied this criterion were delineated as major channel units. Smaller features that still contributed habitat components (e.g., pools along the channel margin within a larger run) were classified as minor channel units.

> **Riffle:** A relatively shallow reach with a gradient of less than 4% with small hydraulic jumps over rough bed material, causing small ripples, waves, and eddies, without breaking the surface tensions. Partial exposure of the substrate (cobble, gravel) is typically present.

Run: A swiftly flowing stream area with a gradient less than 1%, minor surface agitation, waves or turbulence, no major flow obstructions, approximately uniform velocity and depth, substrates of variable size, and water surface slope roughly parallel to the overall stream gradient. Water depth is typically deeper than riffles.

Pool: A relatively low gradient unit (<1%) that is normally deeper and wider than the aquatic habitats immediately above and below it. These units typically have a scour zone with a downstream hydraulic control feature (e.g., deposition area).

Depth: The dimension of a water body measured vertically from the surface to the bottom of the channel. For this study, depth was measured as follows:

Low Flow (Low): Depth was measured at low flow conditions using a calibrated rod. Measurements were taken at three locations along the transect: one quarter, one half, and three quarters of the distance across the transect.

Maximum at Low Flow (Max): Maximum depth of the stream along the transect during measured conditions (i.e., low flow for this study).

Bank Full Depth (BKF): The maximum depth at the measured condition plus the vertical height to the bankfull discharge level (as determined by the apparent annual high water line along the channel bank).

Dominant Substrate: Refers to the relative size class of bottom materials. Substrate types indicate the degree of roughness, the presence of microhabitats and conditions, and can be general indicators of upstream watershed management practices as well. Substrate size classes were measured to the nearest ½ of a foot across the wetted width (transect line) and expressed as a percentage of the total wetted width (Bain and Stevenson, 1999). Size classes are classified according to particle size (in inches) as follows:

Silt and Clay (SC):	<0.002	
Sand (S):	0.002-0.08	(larger than a clay particle, smaller than a pea)
Gravel (G):	0.08-2.5	(pea to tennis ball size)
Cobble (C):	2.5-10	(tennis ball to basketball)
Boulder (B):	10-160	(basketball to small car)
Bedrock (BK):	>160	(larger than a small car)

In-Stream Cover: Cover is defined as the in-stream areas or features that provide protection from predators and adverse environmental conditions such as high current velocities (Murphy and Willis, 1996). Cover was measured in the field to the nearest ½ foot, unless noted otherwise, across the wetted width and expressed as a percentage of the total wetted width (Bain and Stevenson, 1999). Note that the total cover can be grater than 100 percent because of overlapping cover types. The various types of in-stream cover include:

Depth (D): Water depth greater than 3 feet at the measured flow.

Turbulence (T): Cover that results when water movement disturbs the surface and reduces the visibility of objects in the water. Turbulence includes the presence of spray, bubbles, white water, and evident depressions and elevations in the surface.

Undercut Bank (UB): A stream bank with a cavity below the water line that is maintained by scour from substrates and high water velocities.

Overhanging Vegetation (OV): Overhanging riparian vegetation within 5 feet of the water surface.

Aquatic Vegetation (AV): Vegetation that grows on or below the surface of the water for most of the growing season in most years.

Substrate (S): Stream bed substrate material containing an area with cobble size material or larger (i.e., at least 2.5 inches in diameter).

Wood (W): Coarse and large woody debris (from branches to logs).

Trash (TR): Man-made debris larger than 3 feet long (e.g., cars, shopping carts).

Roots (R): Tree and shrub roots adjacent to the riverbank within the water.

Pool Formation: The primary pool formation processes are (1) lateral scour, (2) plunge pool, and (3) dammed pool (Armantrout, 1998; Bain and Stevenson, 1999; Flosi and Reynolds, 1994).

Lateral scour: localized erosion caused by the scouring action of the flow as it is directed laterally or obliquely to one side of the stream by the configuration of the channel or a partial channel obstruction.

Plunge pool: formed by water passing over or through a complete or partial channel obstruction. The water drops steeply into the streambed, scouring out a basin in the substrate.

Impoundment (dammed) pool: formed by impounded water upstream of a channel blockage caused by a beaver dam, log jam, rockslide or a man-made structure.

The main elements or causes of pool formation include boulders, bedrock, woody debris, beaver dams, and channel bends. The elements are classified as either primary or secondary, based on their relative importance in the pool formation.

<u>Residual Pool Volume</u>: The volume of a pool when the discharge approaches zero (Lisle, 1991). The pool tail crest depth was measured at the downstream end of each pool where a hydraulic control (e.g., substrate dam, bedrock) was identified. Pool depth and width were measured to the nearest tenth of a foot incrementally along the thalweg during the survey and recorded on the river plan view map. The pool width boundary was delineated based on water depth (i.e., water depth equal to or greater than the pool tail crest depth). Pool tail crest depth was then subtracted from each depth measurement. Average residual pool depth and width were calculated for each pool and then multiplied by the pool length to get residual pool volume. [Pool cross sectional area was assumed to be triangular].

<u>Riparian Area</u>: Pertaining to the margin of a river or other water body where sufficient soil moisture supports the growth of mesic vegetation that requires a moderate amount moisture. This vegetation is more dependent on water than vegetation that is found further upslope (Armantrout, 1998).

<u>Wetted Perimeter (WP)</u>: The distance along the bottom of the channel. Measured with a chain along the transect line perpendicular to river flow.

<u>Width</u>: The dimension of a water body that is a measure of the cross section shape of a stream channel. A measuring tape was stretched taut across the river to record the following:

> **Wetted Width (Wet):** The width of the water surface measured perpendicular to the direction of flow at a specific transect location to the nearest tenth of a foot. Wetted width reflects the river width at a specific flow, which in this study was approximately mean low flow.
>
> **Bank Full Width (BKF):** The width of the channel at bankfull discharge. The width is measured perpendicular to the direction of flow at a specific transect location to the nearest tenth of a foot. Bankfull discharge is associated with the 1-2 year flood flow. Field indicators include vegetation or bank topography changes along the riverbank, defined scour line (e.g., exposed roots), stain line visible on bare substrate, or a line defining the lower limit of lichen colonization.

<u>Woody Debris</u>: Woody debris includes trees, logs, large limbs, and root wads. Woody debris locations were delineated on the river plan map. Size classes included: small (greater than 0.5 feet but less than 1.0 ft in diameter, and greater than 25 ft in length), medium (greater than 1.0 feet but less than 2.0 ft in diameter, and greater than 25 ft), and large (greater than 2.0 feet in diameter, and greater than 25 ft). Pieces less than 25 ft were not mapped. Size classes were selected based on their stability and effects on channel morphology (Kaufmann and Robison, 1997).

<u>Velocity</u>: The speed at which water travels downstream, expressed in feet per second for this study. Velocity was measured using a Marsh-McBirney (Flow Mate®) at three points along the transect: one quarter, one half, and three quarters of the distance across the transect. At each point, where water depths were less than 3 feet, velocity measurements were taken at 0.6 the depth from the surface. Where water depths were greater than 3 feet, measurements were taken at 0.2 and 0.8 the depth, and then averaged.

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Aquatic Habitat Field Form

Page ___ of ___

Date ____________________________ Observer/Recorder __________________________
River____________________________ Weather___________________________________
Reach___________________________ Discharge (cfs)_______________________________

Station______________________ Transect______________________

Habitat Unit__________________

Width (ft): Depth (ft): Wetted

Wet_______________ Low_______ _______ _______ perimeter (ft)____________
BKF_______________ Max______________________
BKF______________________

Dominant substrate (ft): SG______ S______ G______ C______ B______ BK______

In-stream cover (ft): D______________ T______________ UB_____________
OV_____________ AV_____________ S_______________
W______________ TR______________

Velocity (ft/s): ____________ ____________ ____________

Densiometer (# hits)
Left_________________
Upstream_____________
Downstream___________
Right________________

% Bank Stability
Left_____/_____
Right_____/_____

Comments:

Photos:

Habitat Size:

Length (ft)_____________________ Avg. width (ft)_____________________________
Pool tail crest depth (ft)___________ Avg. Depth (ft)_____________________________
Surface area (ft^2)________________ Residual volume (ft^3)________________________

Appendix B

River Plan View Maps

Appendix C

Aquatic Habitat Characteristics

Transect Summary

APPENDIX C

Table C-1. Aquatic Habitat Characterization: Channel Depth, Width, and Velocity:

1 1/2 Mile Reach, Pittsfield. MA; 24-26 July, 2000.

Reach	Subreach	Station	Transect	Habitat	Depth (ft)							Width (ft)		Wetted	WP/Wet	BKF	Velocity (ft/s)				
			#	Unit	Low 1	Low 2	Low 3	Avg. Low	StDev	Max	BKF	Wet	BKF	Perimeter (ft)	(%)	W/D	1	2	3	Avg	StDev
1	3-8	1+05	66	pool	1.5	2.2	3.6	2.4	1.1	3.8	5.8	51.5	56.5	58	113	9.7	0.1	0.5	0.6	0.4	0.1
1	3-8	3+05	70	pool	1	1.1	2.2	1.4	0.7	2.5	4.7	63.5	67.5	68	107	14.4	0.6	0.9	0.5	0.7	0.3
1	3-8	5+10	74	run	2.2	1.1	0.7	1.3	0.8	2.8	5	62.5	69.5	66	106	13.9	0.7	0.8	0.1	0.5	0.5
1	3-8	7+10	78	run	2.9	2.2	2.9	2.7	0.4	3.2	5.5	59	63.5	66	112	11.5	0.2	0.6	0.3	0.4	0.2
1	3-9	9+20	82	pool	4.5	4.1	1.7	3.4	1.5	5.5	7.5	44.5	61.5	47.5	107	8.2	0.3	0.4	0.5	0.4	0.1
1	3-9	12+0	88	run	2.3	2.6	2.9	2.6	0.3	2.9	4.9	59	65	65	110	13.3	0.5	0.7	0.1	0.4	0.4
1	3-10	15+25	94	pool	3.5	4	4.5	4.0	0.5	4.5	6.2	50	64	53	106	10.3	0.1	0.1	0.2	0.1	0.1
1	3-10	16+10	102	pool	2.3	3	2.3	2.5	0.4	3.9	5.4	54.5	58	62	114	10.7	0.3	0.7	0.4	0.5	0.2
1	3-10	21+45	106	pool	3.8	2.8	3.1	3.2	0.5	4.5	6.5	48	55	51	106	8.5	0.4	0.4	0.2	0.3	0.1
2	4-1	24+20	112	pool	1.1	2.3	2.3	1.9	0.7	2.4	4.1	48.5	55.5	57	118	13.5	0.1	0.9	1	0.7	0.1
2	4-2	26+50	116	riff	0.3	1.2	1.3	0.9	0.6	1.6	3.1	46	55	49	107	17.7	0.5	3.1	2.1	1.9	0.7
2	4-2	28+50	120	run	1.2	2.2	1.9	1.8	0.5	2.2	3.7	32	43.5	35	109	11.8	1.1	1.9	0.4	1.1	1.1
2	4-2	30+10	124	pool	2.8	2.4	1.2	2.1	0.8	3	5	36	45	42	117	9.0	0.3	1.1	0.5	0.6	0.4
2	4-2	32+20	128	pool	1.7	2.3	1.8	1.9	0.3	2.3	3.5	43	62	48	112	17.7	0.6	0.4	1.4	0.8	0.7
2	4-3	34+10	132	pool	2.8	3.2	2.9	3.0	0.2	3.4	4.4	34	45	40	118	10.2	1.8	0.2	-0.1	0.6	0.2
2	4-3	36+20	136	riff	1.3	1	0.9	1.1	0.2	1.7	3.2	36	41	44	122	12.8	0	2.4	1.8	1.4	0.4
2	4-3	38+20	140	pool	2	2	1.7	1.9	0.2	2.2	3.5	35.5	40	38	107	11.4	0.6	0.7	0.7	0.7	0.0
2	4-3	40+40	144	run	1.1	2.3	1.7	1.7	0.6	2.3	4.1	49	54	51	104	13.2	0.5	1.1	0.7	0.8	0.3
2	4-3	42+40	148	riff	0.5	0.7	1.3	0.8	0.4	1.4	2.9	32	55.5	34	106	19.1	1.3	2.7	3.2	2.4	0.4
3	4-4A	44+10	152	riff	1.3	0.4	0.2	0.6	0.6	1.5	3.3	53	61	56	106	18.5	2.4	0.9	0.5	1.3	0.3
3	4-4B	46+20	156	run	1.6	2.2	2	1.9	0.3	2.2	4.2	37.5	42.5	45	120	10.1	0.5	1.3	0.6	0.8	0.5
3	4-4B	48+10	160	run	1.1	1.3	0.8	1.1	0.3	2.3	4.8	45.5	55	48	105	11.5	0.1	1.5	1.2	0.9	0.2
3	4-4B	50+40	164	riff	1.3	1.6	0.9	1.3	0.4	1.8	3.8	40	42.5	45	113	11.2	1.2	1.4	0.9	1.2	0.4
3	4-5A	53+45	170	riff	1.1	0.7	1	0.9	0.2	1.7	3.7	49	57	52	106	15.4	2.3	1.6	0.1	1.3	1.1
3	4-5A	56+30	176	run	1.7	1.4	1.4	1.5	0.2	1.8	4.3	47	53	51	109	12.3	1	1	0.8	0.9	0.1
3	4-5A	59+30	182	riff	0.9	0.6	0.6	0.7	0.2	1.6	3.6	54.4	59.5	59	108	16.5	2.3	1.8	1.3	1.8	0.4
3	4-5B	62+40	188	pool	1.2	1.8	1.7	1.6	0.3	2.2	4.7	39.5	48	42	106	10.2	0.9	1.1	0.5	0.8	0.4
3	4-5B	65+50	194	run	0.8	1.2	1.7	1.2	0.5	1.8	3.8	46.5	53.5	48	103	14.1	1	1.6	1.2	1.3	0.3
3	4-6	68+40	200	pool	0.9	2.4	2.1	1.8	0.8	2.9	4.9	47	52	49	104	10.6	0.9	0.9	0.7	0.8	0.1
3	4-6	71+40	206	run	0.8	1.4	1.6	1.3	0.4	1.6	4.6	41	58	44	107	12.6	1.4	2.8	1.3	1.8	1.1
Average for All Reaches Combined					1.72	1.92	1.83	1.82	0.49	2.6	4.5	46.2	54.6	50.5	110	12.67	0.80	1.18	0.79	0.92	0.37
StDev for All Reaches Combined					1.01	0.94	0.95	0.85	0.30	1.0	1.1	8.7	8.1	9.2	5	2.97	0.68	0.78	0.69	0.54	0.29
Average for Reach 1					2.67	2.57	2.66	2.6	0.7	3.73	5.72	54.7	62.3	59.6	109	11.17	0.36	0.57	0.32	0.41	0.22
StDev for Reach 1					1.12	1.07	1.10	0.9	0.4	0.98	0.89	6.7	5.0	7.5	3	2.27	0.21	0.24	0.19	0.15	0.16
Average for Reach 2					1.48	1.96	1.70	1.7	0.5	2.25	3.75	39.2	49.7	43.8	112	13.65	0.68	1.45	1.17	1.10	0.42
StDev for Reach 2					0.85	0.76	0.58	0.6	0.2	0.61	0.65	6.7	7.6	7.4	6	3.43	0.56	1.01	0.98	0.62	0.32
Average for Reach 3					1.15	1.36	1.27	1.3	0.4	1.95	4.15	45.5	52.9	49.0	108	13.00	1.27	1.45	0.83	1.18	0.44
StDev for Reach 3					0.30	0.63	0.61	0.4	0.2	0.42	0.55	5.5	6.3	5.2	5	2.78	0.76	0.54	0.39	0.37	0.33

BKF=Bankfull; Wet=Wetted width.

Note: No data were collected at Transect #98 in Reach 1 (a pool) because the unit was > 6' deep -- too deep to wade.

APPENDIX C

Table C-2. Aquatic Habitat Characterization: Substrate, In-Stream Cover, Bank Stability, and Riparian Cover:
1 1/2 Mile Reach, Pittsfield, MA; 24-26 July, 2000.

Reach	Subreach	Station	Transect	Habitat							Total	In-stream Cover (%)									Total		Densiometer (# hits)				Total	Total
			#	Unit	SC	S	G	C	B	BK	%	D	T	UB	OV	AV	S	W	TR	R	Cover (%)	Stability (%)	Left	US	DS	Right	Hits	Cover (%)
1	3-8	1+05	66	pool	4	70	14	0	12	0	99	19	0	0	0	0	12	12	0	0	43	100	17	0	6	0	23	34
1	3-8	3+05	70	pool	46	25	25	0	0	0	96	0	0	2	0	0	0	19	3	0	24	100	16	2	3	17	38	56
1	3-8	5+10	74	run	26	21	53	0	0	0	99	0	0	0	3	0	0	0	2	0	5	95	17	7	2	17	43	63
1	3-8	7+10	78	run	32	68	0	0	0	0	100	7	0	0	0	0	0	7	7	0	20	100	11	2	1	17	31	46
1	3-9	9+20	82	pool	49	38	11	0	0	0	99	54	0	0	22	0	0	0	0	0	76	90	14	7	2	17	40	59
1	3-9	12+0	88	run	24	17	17	34	8	0	100	0	0	0	0	0	8	3	8	0	20	95	17	14	12	17	60	88
1	3-10	15+25	94	pool	94	0	0	0	6	0	100	80	0	0	6	0	0	0	0	0	86	100	17	0	0	17	34	50
1	3-10	16+10	102	pool	26	33	0	40	0	0	99	50	0	2	2	0	40	4	9	0	106	85	16	3	2	17	38	56
1	3-10	21+45	106	pool	0	54	0	38	8	0	100	52	0	0	6	0	92	10	2	0	163	85	17	7	6	17	47	69
2	4-1	24+20	112	pool	6	23	0	70	0	0	99	0	0	0	14	0	70	0	2	0	87	100	16	8	10	17	51	75
2	4-2	26+50	116	riff	0	0	0	100	0	0	100	0	54	0	0	0	87	0	0	0	141	95	14	4	0	17	35	51
2	4-2	28+50	120	run	6	25	0	9	22	38	100	0	53	0	6	0	69	3	0	0	131	100	17	2	1	17	37	54
2	4-2	30+10	124	pool	3	6	0	92	0	0	100	11	0	0	6	0	92	0	0	0	108	100	17	9	5	10	41	60
2	4-2	32+20	128	pool	0	19	26	49	7	0	100	0	21	0	7	0	51	2	0	0	81	95	14	0	3	5	22	32
2	4-3	34+10	132	pool	0	21	12	68	0	0	100	79	29	3	0	0	68	3	0	0	182	100	8	1	0	17	26	38
2	4-3	36+20	136	riff	0	0	0	100	0	0	100	0	0	0	0	0	100	0	72	0	172	100	5	0	0	15	20	29
2	4-3	38+20	140	pool	0	17	37	34	11	0	99	0	0	0	0	0	62	0	3	0	65	95	5	0	1	16	22	32
2	4-3	40+40	144	run	6	16	41	33	4	0	100	0	80	0	6	0	45	4	4	0	139	95	17	4	8	15	44	65
2	4-3	42+40	148	riff	0	0	47	47	6	0	100	0	0	0	0	0	94	0	0	6	100	100	3	12	5	16	36	53
3	4-4A	44+10	152	riff	8	2	75	15	0	0	100	0	85	0	0	0	15	2	0	0	102	85	17	8	1	17	43	63
3	4-4B	46+20	156	run	24	32	11	32	0	0	99	0	0	0	11	0	32	11	3	0	56	95	8	8	7	17	40	59
3	4-4B	48+10	160	run	22	18	59	0	0	0	99	0	0	0	0	0	2	11	9	0	22	96	17	15	16	16	64	94
3	4-4B	50+40	164	riff	8	10	38	45	0	0	100	0	0	0	3	0	35	3	0	3	43	90	17	6	4	14	41	60
3	4-5A	53+45	170	riff	35	12	45	8	0	0	100	0	49	0	12	0	0	2	0	4	67	95	17	1	2	17	37	54
3	4-5A	56+30	176	run	11	83	6	0	0	0	100	0	0	0	9	0	0	0	0	0	9	95	16	16	15	17	64	94
3	4-5A	59+30	182	riff	11	37	51	0	0	0	99	0	0	0	18	0	0	17	2	0	37	95	17	1	8	17	43	63
3	4-5B	62+40	188	pool	0	63	20	18	0	0	101	0	0	0	13	0	18	8	8	0	46	90	17	5	2	17	41	60
3	4-5B	65+50	194	run	11	89	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	90	10	3	7	17	37	54
3	4-6	68+40	200	pool	21	57	21	0	0	0	100	0	0	0	21	0	0	0	0	0	21	85	17	6	4	14	41	60
3	4-6	71+40	206	run	27	54	20	0	0	0	100	0	0	0	0	0	0	0	0	0	0	85	3	2	0	15	20	29
Average for All Reaches Combined					17	30	21	28	3	1	100	12	12	0	6	0	33	4	4	0	72	94	14	5	4	15	39	57
StDev for All Reaches Combined					20	26	22	32	5	7	1	24	25	1	7	0	36	5	13	1	54	5	5	5	4	4	12	17
Average for Reach 1					33	36	13	12	4	0	99	29	0	0	4	0	17	6	3	0	60	94	16	5	4	15	39	58
StDev for Reach 1					28	24	17	19	5	0	1	30	0	1	7	0	31	7	4	0	52	6	2	5	4	6	10	15
Average for Reach 2					2	13	16	60	5	4	100	9	24	0	4	0	74	1	8	1	121	98	12	4	3	15	33	49
StDev for Reach 2					3	10	19	31	7	12	1	25	29	1	5	0	19	2	23	2	39	3	6	4	4	4	11	15
Average for Reach 3					16	42	32	11	0	0	100	0	12	0	8	0	9	5	2	1	37	91	14	6	6	16	43	63
StDev for Reach 3					11	30	24	15	0	0	1	0	28	0	8	0	14	6	3	1	31	4	5	5	5	1	12	18

Substrates: SC=Silt clay; S=Sand; G=Gravel; C=Cobble; B=Boulder; BK=Bedrock (Refer to Appendix A for definitions).
In-stream Cover: D=Depth; T=Turbulence; UB=Undercut banks; OV=Overhanging vegetation; AV=Aquatic vegetation; S=Substrate; W=Wood; TR=Trash; R=Roots (Refer to Appendix A for definitions).
Note: No data were collected at Transect #98 in Reach 1 (a pool) because the unit was > 6' deep -- too deep to wade.

Appendix D

Aquatic Habitat Characteristics

Channel Unit Types, Pool Characteristics, and Woody Debris

APPENDIX D - Aquatic Habitat Characteristics - Channel Unit Types, Pool Characteristics, and Woody Debris

Channel Unit Type, Size, and Location

Reach	Station #	NSO[1]	Channel Unit	Unit #	Length (ft)	Avg. Width (ft)	Surface Area (ft^2)
1	00-10	1	Pool	P1	415	58	23,863
1	04+05	2	Run	RU1	355	61	21,566
1	07+60	3	Pool	P2	280	55	15,344
1	10+40	4	Run	RU2	320	59	18,880
1	13+60	5	Pool	P3	830	51	42,189
2	21+90	6	Riffle	R1	90	35	3,150
2	22+80	7	Run	RU3	145	40	5,800
2	24+25	8	Pool	P4	130	50	6,500
2	25+55	9	Pool	P5	45	48	2,160
2	26+00	10	Riffle	R2	250	43	10,750
2	28+50	11	Run	RU4	125	35	4,375
2	29+75	12	Pool	P6	125	36	4,500
2	31+00	13	Riffle	R3	80	45	3,600
2	31+80	14	Pool	P7	65	43	2,795
2	32+45	15	Riffle	R4	105	48	5,040
2	33+50	16	Pool	P8	230	34	7,820
2	35+80	17	Riffle	R5	195	36	7,020
2	37+75	18	Pool	P9	105	38	3,990
2	38+80	19	Riffle	R6	135	52	7,020
2	40+15	20	Run	RU5	75	49	3,675
2	40+90	21	Riffle	R7	510	54	27,540
3	46+00	22	Run	RU6	280	42	11,620
3	48+80	23	Pool	P10	170	45	7,650
3	50+50	24	Riffle	R8	325	49	15,925
3	53+75	25	Run	RU7	535	47	25,145
3	59+10	26	Riffle	R9	70	55	3,815
3	59+80	27	Run	RU8	305	40	12,048
3	62+85	28	Pool	P11	145	45	6,525
3	64+30	29	Run	RU9	280	47	13,020
3	67+10	30	Pool	P12	195	47	9,165
3	69+05	31	Run	RU10	355	41	14,555
3	72+60	32	Pool	P13	45	50	2,250
3	73+05	33	Pool	P14	245	60	14,700

Pool Characteristics

Reach	Unit #	Pool Formation			Length (ft)	Avg. Width (ft)	Max. Depth (ft)	Avg. Depth (ft)	Pool Tail Crest (ft)	Residual Volume (ft^3)
		Process	Primary Cause	Secondary Cause						
1	P1	L.Scour	Channel Bend	Riprap	415	21	4.5	3.3	1.3	8669
1	P2	L.Scour	Channel Bend	Woody Debris	280	20	5.6	4.5	2.7	5088
1	P3	Impound	Bedrock	Channel Bend	830	51	>6.0	5.0	1.4	75940
				Reach 1 Totals	**1525**					**89,697**
2	P4	Impound	Boulder (Trash-concrete)	None	130	48	3.7	3.3	1.6	5148
2	P5	Plunge	Boulder	None	45	47	3.1	2.6	2.1	555
2	P6	L.Scour	Channel Bend	Cobble	125	41	3.5	2.8	1.8	2665
2	P7	Plunge	Bedrock	Boulder	65	43	3.7	2.9	1.4	2040
2	P8	Plunge	Bedrock	Constriction (channel)	230	34	4.2	2.8	1.5	5161
2	P9	L.Scour	Bar (cobble)	Woody Debris	105	21	2.9	2.4	1.7	775
				Reach 2 Totals	**700**					**16,344**
3	P10	L.Scour	Channel Bend	Outfall	170	22	4.0	2.8	1.2	2872
3	P11	L.Scour	Woody Debris	Boulder	145	13	2.8	2.0	0.5	1446
3	P12	L.Scour	Riprap	Woody Debris	195	20	3.6	2.6	1.6	1936
3	P13	L.Scour	Woody Debris	None	45	13	1.7	1.3	0.6	222
3	P14	L.Scour	Woody Debris	Channel Bend	240	25	3.9	2.8	1.2	4800
				Reach 3 Totals	**795**					**11277**
				Grand Totals	**3,020**					**117,318**

NOTES:

1. NSO = Natural Sequence Order
2. Woody Debris Size Classes: Small = Diameter > 0.5' to 1' and Length > 25'
   Medium = Diameter > 1' to 2' and Length > 25'
   Large = Diameter > 2' and Length > 25'
3. Woody Debris Change: Indicates the number of new pieces gained when 2000 survey is compared to 1998 survey (Woodlot Alternatives, 1999).
   A "+" indicates pieces not present previously, a "-" indicates pieces previously present.

Woody Debris: Number of Pieces, By Size Class

Reach	Size Class[2]			Totals	Change[3]	
	Small	Medium	Large		+	-
1	18	17	4	39	11	8
2	8	4	1	13	7	4
3	26	18	2	46	16	12
Totals	52	39	7	98	34	24

Appendix E

Fish Species Documented In The Housatonic River Near Pittsfield, Massachusetts

APPENDIX E: Fish Species Documented in the Housatonic River Near Pittsfield, MA.

Species	Common name	Estimated Relative Abundance in EE/CA Reach *	Habitat	Preferred Temp Range	Preferred pH Range	Spawning Habitat	Comments
Micropterus salmoides	Bass, Largemouth	C	Benthopelagic; Prefers quiet, clear water and over-grown banks.	50 - 89° F	7.0 - 7.5	Mud, sand or leaf litter, or among roots of aquatic plants.	Highly-prized gamefish, but not as prized as smallmouth bass.
Ambloplites rupestris	Bass, Rock	C	Demersal; vegetated and brushy stream margins and pools of creeks and small to medium rivers; most commonly found in clear, silt-free rocky streams.	50 - 84°F	7.0	Gravely shoreline areas.	Can seriously compete with smallmouth bass for food.
Micropterus dolomieui	Bass, Smallmouth	U	Demersal; clear and gravel-bottom runs and flowing pools of rivers.	50 - 86°F	-	Gravel or rubble bottom with nearby cover (boulder or log), in 2-12' of water.	Highly-prized gamefish.
Lepomis macrochirus	Bluegill Sunfish	C	Benthopelagic; lakes, ponds, reservoirs and sluggish streams; preferably lives in deep weed beds.	39 - 89°F	7.0 - 7.5	Gravely substrate in shallow water.	Can be a highly-valued gamefish, but tends to overpopulate waters where it is found.
Ameiurus nebulosus	Bullhead, Brown	U	Demersal, brackish pools and sluggish runs over soft substrates in creeks and small to large rivers.	39 - 86°F	-	Sandy bottom; in water <2 ft. deep; near or under shelter (log, rock, overhanging bank)	Can tolerate high carbon dioxide and low oxygen concentrations; resistant to domestic and industrial pollution.
Pomoxis nigromaculatus	Crappie, Black	U	Benthopelagic; backwaters and quiet pools, usually clean water with vegetation and sand or mud substrate.	-	-	Sand or mud bottom in 3-8' of water, often among rooted vegetation.	Can be a highly-valued gamefish.
Rhinichthys atratulus	Dace, Blacknose	U	Demersal; rocky runs and pools of headwaters, creeks and small rivers.	54 - 68°F	-	Riffles of streams, nest of pebbles.	Often an important forage fish for trout.
Rhinichthys cataractae	Dace, Longnose	C	Demersal; rubble and gravel riffles (sometimes runs and pools) of fast creeks and small to medium rivers.	39 - 61°F	7.0	Riffles over rock or gravely bottom.	Often an important forage fish for trout.
Semotilus corporalis	Fallfish	C	Demersal; gravel- and rubble-bottomed pools and runs of small to medium rivers.	-	-	Quiet stretches of stream, communal nest of pebbles and stone.	Important source of food for predatory gamefish. A common bait fish.
Pimephales notatus	Minnow, Bluntnose	U	Demersal; almost anywhere in its range but most common in clear rocky streams.	-	-	Small depressions beneath flat rocks.	
Perca flavescens	Perch, Yellow	A	Benthopelagic; lakes, ponds, pools of creeks, and rivers in clear water near vegetation.	up to 84°F	-	Shallow backwaters when water temp reaches mid-40°'s F; in submerged veg. or branches of fallen trees.	Important forage fish and game fish, but can become overpopulated and stunted.
Esox niger	Pickerel, Chain	U	Demersal; vegetated lakes, swamps, and backwaters and quiet pools of creeks and small to medium rivers.	50 - 68°F	-	Marshy backwaters in aquatic vegetation.	Adults are voracious predators of fish, frogs, and often ducklings.
Esox lucius	Pike, Northern	U	Demersal; clear vegetated lakes, quiet pools and backwaters of creeks and small to large rivers.	50 - 82°F	-	Marshy areas with vegetation in water usually less than 17.8 cm; water temp of 50°F.	Can be a prized sportfish.
Lepomis gibbosus	Pumpkinseed Sunfish	U	Benthopelagic; quiet and vegetated lakes, ponds, and pools of creeks and small rivers.	39 - 72°F	7.0 - 7.5	Sand or gravel in very shallow waters (1-3 ft.) near the shore.	Can cause problems associated with overpopulation, harming other more economically-important fisheries.
Luxilus cornutus	Shiner, Common	C	Demersal; rocky pools near riffles in clear, cool creeks and small to medium rivers.	-	-	Running water and clean gravel bottom when temp is >60°F.	Important forage and bait fish.
Notemigonus crysoleucas	Shiner, Golden	C	Demersal; sluggish streams or lakes with thick aquatic growth and mud bottoms.	up to 87°F	-	Scatters adhesive eggs over submerged aquatic vegetation in quiet water.	Valuable as a forage fish for game species.
Notropis hudsonius	Shiner, Spottail	C	Demersal; sandy and rocky pools and runs of small to large rivers.	-	-	Submerged aquatic vegetation in quiet water.	Valuable as a forage fish for game species; a common bait fish.
Catostomus commersoni	Sucker, White	C	Demersal; very adaptable to all temperatures, substrates, flow rates, and vegetative conditions. Bottom dweller, but typically avoids deep water.	39 - 87°F	-	Gravelly areas of shallow, swift-flowing streams.	Valuable as a forage fish for game species and as bait.
Salvelinus fontinalis	Trout, Brook	U	Wide range of habitats, including swift mountain streams, sluggish meadow brooks, rivers, lakes. Inhabits mud, gravel, or bedrock bottom substrates, heavy weed to open water. Requires year-round supply of cold (<68° F), oxygenated water, but can tolerate higher temperatures for short periods.	41 - 72°F	-	Gravel-bottomed, spring-fed tributaries.	A favored game fish, normally stocked.
Salmo trutta	Trout, Brown	U	Typically found in deep, quiet pools or slow-moving, usually warmer lower sections of stream, but also does well in fast-flowing streams.	up to 75°F	-	Gravely-bottom riffles of spring-fed tributaries.	Brown trout are adaptable and can live under less favorable conditions than brook trout. Can be difficult for anglers to catch.
Salmo gairdneri	Trout, Rainbow	U	Swift riffles to deep pools of streams, as well as lakes. Thrives best in cold water, with swift riffles but can tolerate relatively high temperatures (up to 85° F).	50 - 75°F	-	Swift riffle area with gravel bottoms.	Thrives best in cold water, but can tolerate relatively high temperatures (up to 85 F). Some native populations are anadromous.

<u>* Abundance:</u>

A = Abundant: large numbers recorded

C = Common: many recorded

U = Uncommon: present, but only few recorded

Note: Blank cells in the table indicate that no data were readily available.

Appendix F

Macroinvertebrate Characterization

(Not available – Results due April 2000)

Appendix G

Macroinvertebrate PCB Tissue Concentrations

(Not available – Results due November 2000)

Appendix H

Aquatic and Riparian Habitat Restoration Objectives

Appendix H

Aquatic and Riparian Habitat Restoration Objectives for the 1 ½ Mile Reach

This attachment describes habitat restoration objectives (HROs) for the 1 ½ Mile Reach. These objectives, first presented in an Engineering Evaluation/Cost Analysis report (R.F. Weston, 2000) prepared in February 2000, are described in more detailed below. HROs have been developed to insure that the functions and values that the aquatic and riparian habitat provide are maintained and enhanced following the removal action, and that restoration is performed in accordance with the Consent Decree agreed by GE, the Trustees, USEPA, the Commonwealth of Massachusetts, the City of Pittsfield, the Pittsfield Economic Development Authority, and the State of Connecticut. This attachment also provides examples of methods that can be used to restore and enhance habitat in an ecologically sound manner.

General HROs originally presented in the EE/CA report were as follows:

- Implement the Removal Action for the 1 ½ Mile Reach as approved by EPA;
- Perform the restoration, including the enhancement of the river sediment and bank habitat, to increase the diversity and productivity of the biological community;
- Restore the riverbank to provide overlying cover, to enhance the bank vegetation by establishing plantings using native species; and
- Minimize the potential for erosion of residual PCB-containing bank soils and river sediments that would result in recontamination of river sediments or transport of PCBs, and which could impair the river restoration by adversely impacting the ecological receptors.

The riparian HROs were re-evaluated based on the planting requirements and specifications described in the EE/CA and were found to be acceptable for meeting the restoration objectives. These HROs have not been changed. The results of the aquatic habitat assessment were used to more fully develop the aquatic HROs. The aquatic HROs for the 1 ½ Mile Reach will be supplemented as follows:

- *Increase the variability in velocity and in low-flow channel width.* Stream velocity is the speed at which water flows in the river channel. The low-flow channel width is the area that the stream occupies during typical low-flow periods, usually late summer. Velocity changes in the stream as water passes over and around objects such as large woody debris (i.e., dead trees) and boulders. Increased velocities occur along the edges of the object, and decreased velocities occur in eddies that typically form behind the debris. Increased velocities increase oxygen exchange and enhance habitat, while decreased velocities in eddies and pools enhance habitat by providing feeding cover for fish. Increasing the variability of the low-flow channel width increases natural diversity in the stream by changing the flow dynamics and providing more types of habitat for aquatic species. It also enhances habitat value by decreasing stream homogeneity, like that currently found in previously channelized portions of the 1 ½ Mile Reach.

- *Increase the diversity and amount of substrate cover types and water turbulence cover types.* Substrate cover types can include cobbles, large rocks, boulders, and large woody debris. These cover types provide feeding and cover habitat for fish and macroinvertebrates. Water turbulence cover is typically provided by riffles in the river, which visually obstruct views into the water from above. Piscivorous birds, such as belted kingfishers, are unable to forage in these areas because they can't see the fish through the turbulence.

The methods and materials proposed to achieve these objectives include installing single- and double-wing deflectors, rock weirs (e.g., W, vortex, and J), and individual and clustered boulder and cobble placements. Appropriate methods and materials will be chosen during design to insure that erosion does not occur in undesirable locations.